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A Monthly Journal devoted to the Arts and Sciences Related to the Silicate Industries

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AMERICAN CERAMIC SOCIETY

A monthly journal devoted to the arts and sciences related to the silicate industries.

Editor: E. W. WASHBURN; **Associate Editors:** L. E. BARRINGER, A. V. BLEININGER, R. L. CLARE, E. P. POSTE, H. RIES, F. H. RHEAD, R. B. SOSMAN, R. T. STULL, E. W. TILLOTSON

Vol. 4 **August, 1921** **No. 8**

EDITORIAL

THE SUMMER MEETING

There is a family likeness among the meetings of the Society which take place from time to time. They partake of the characteristics of a social reunion and of a business convention. The meeting which assembled at Canton, Ohio, on the morning of July 25 was no exception. Perhaps it is rather a pity that one so often sees the same faces, but on the other hand there is in this a sense of brotherhood that would not be there if all were strangers. Yet there are always some who attend for the first time, to which may be added the significant remark that nearly all of these say they will surely come the next time.

The forenoon of the first day was spent in inspecting the huge plant of the Dueber Watch Case Company, a place where not only the cases but the complete watch, from the swaging of the filled bars of metal to the enameling of the face and the printing of the hours on the dial, may be seen in process of production. Only a few workers were employed but there was somebody at work at every job.

After luncheon the party, now about one hundred strong, proceeded to the plant of the Canton Stamping and Enameling Company, where a uniform grade of granite household ware is produced. The whole process was carefully explained by Royal W. Taylor and his assistants and the visitors were even permitted to enter the mixing room.

Toward evening two large buses appeared at the hotel and these, supplemented by numerous private cars, conveyed the crowd to Congress Lake, eighteen miles away, where at the Country Club an excellent dinner was served. There was, of course, the usual provision for dancers but the ladies were greatly in the minority, so that it was announced to be in order that any man might "cut in" as he pleased.

After dinner there were two or three brief speeches and a story telling entertainment by a well known raconteur. Mr. Stull announced that a presentation was to be made to Professor Binns and a steward started up the hall with a huge glass punch bowl. Upon reaching the center of the table he conveniently slipped and fell so that the bowl was removed by a broom and dust pan to the relief of the donee.

Tuesday morning was devoted to the plant of the Alliance Brick Company which was reached by automobile. Here was seen an admirably equipped plant making rough faced brick and a new Richardson Chamber Kiln fired by producer gas. At the Alliance Country Club an excellent luncheon was served to the party which now numbered one hundred and fifty. The next move was to Sebring where were visited the plants of the Sebring Pottery Company, the Limoges China Company, where a newly installed tunnel kiln was the center of attraction, and the Strong Enamel Manufacturing Company. A special car conveyed the members back to Canton where an evening's entertainment in the form of a smoker was provided.

On Wednesday morning an early start by motor bus and automobile was made for East Liverpool which was reached about half past ten. The R. Thomas & Sons Company's plant was visited at once and at noon a liberal luncheon was served at the Elk's Club, which place also provided a hospitable headquarters during the day. After luncheon Mr. W. E. Wells gave one of his inimitable addresses and then the street cars conveyed the crowd to the mammoth plant of the Homer Laughlin China Company across the river. Here different groups were conducted by guides for the inspection of equipment and process and a profitable time was spent.

The Edwin M. Knowles China Company's plant was then visited and the party returned to the Elk's Club to separate finally for the journey home.

It is difficult to compare one meeting with another and as the membership grows it is to be expected that numbers will increase but it is certainly true that the meeting of 1921 was the largest and most generally enjoyed of any in the history of the Society. Much of this success is due to the efforts of Ira E. Sproat and the local committee of which he was chairman. Resolutions of thanks to them and to the firms who generously assisted were passed at the Wednesday luncheon.

ORIGINAL PAPERS AND DISCUSSIONS

THE CAUSES AND CONTROL OF FISH SCALING OF ENAMELS FOR SHEET IRON AND STEEL [1]

By R. R. Danielson and W. H. Souder

ABSTRACT

Data obtained.—This paper presents measurements of the following factors and properties and their influences upon fish scaling in the case of typical single and three-coat enamels: time and temp. during melting of the frit; fusibility of the enamel; coeff. of expansion of the enamel, and of a variety of representative irons and steels up to 500°C (accuracy about 0.1%); annealing the enamel coat after firing; chem. comp. of the steels and irons; mechanical treatment (rolling, spinning, drawing, and so forth of the stock; microscopic surface structure of the stock; effect of chem. comp. upon thermal expansion of enamel.

Incidentally it was found that the formulas of Mayer and Havas for computing the thermal expansion of enamel from its chem. comp. can not be relied upon.

Conclusions.—On the basis of these exhaustive tests, the following conclusions have been drawn as to the causes and the control of fish scaling.

(A) Causes.—1. The cause of fish scaling lies in the difference of the coefficients of expansion of the enamel and the stock, that for steel being higher than for enamels so that the latter are under a compressive stress. The factors influencing this phenomenon are as follows: (*a*) Composition of the enamel as affecting the coefficient of expansion of the enamel; (*b*) Overfiring—thus volatilizing those substances which tend to keep the coefficient high; (*c*) Lack of annealing enameled ware, the enamel coating of which is a *glass* and should logically be treated as such.

2. Fish scaling is due secondarily to a number of factors which may affect the strength of the enamel or its adherence to the metal. (*a*) The physical condition of the surface of the metal as influenced by drawing, spinning, cold rolling or other mechanical treatment; (*b*) Composition of the glass as affecting its elastic strength; (*c*) Underfiring, enamel not fused to metals; (*d*) Cleanliness of the surface as regards removal of drawing compounds, grease, etc.

[1] Received June 13, 1921. Published by permission of the Director, Bureau of Standards.

(B) Remedies.—1. (*a*) Adjusting the composition of the enamel so as to increase its coefficient, *e. g.*, by decreasing the boric acid content; (*b*) Correct firing of the enamel to avoid unnecessary volatilization of such fluxes as soda and cryolite; 2. (*a*) Adjusting enamel composition to increase its strength; (*b*) Correct firing to give proper adherence. 3. Treatment of metal to give best adhesion by (*a*) cold rolling or other suitable mechanical treatment of the untreated steel; (*b*) thorough cleaning.

(C) Summary.—Broadly stated, then, fish scaling can be absolutely controlled by one or all of the following methods: (1) By the development of an enamel with an expansion fitting the metal; (2) by annealing the enameled ware; (3) by treatment of the metal as cold rolling or some other method of working; (4) by developing an enamel with a wide range of compressional elasticity and applying this enamel to metal treated as indicated above.

The subject of fish scaling of enamels has been much discussed among enamelers but comparatively little systematic investigation has been carried out in spite of the enormous losses occasioned in the industry by this defect, the only work recorded being that of Shaw.[1] Fish scaling may be defined as the spontaneous chipping or scaling of small particles of enamel from an enamel surface. These scales may vary from $^1/_{64}$ to $^3/_8$ of an inch in diameter and appear to be confined to the enamel surface although on close examination they are usually found to extend down to the steel, the extent of fracture depending on the type and size. The smaller scales are usually very numerous while the larger type are generally few in number.

The Enameled Metals Section of the Bureau of Standards has been conducting during the past year and a half an extended investigation of this subject, and preliminary reports were presented at the annual meeting of the American Ceramic Society in February, 1920, and also at a joint conference of the Enamel Division of the Society and the Sheet Metal Ware Manufacturers Association at this Bureau, June 15, 1920. In attacking this problem, the initial work was done on gray ware enamels since these are the least complex in composition and in method of application. As a basis for the compounding of the enamels, an average of several commercial formulas, having the following composition, was selected:

[1] J. B. Shaw, "Fish Scaling," THIS JOURNAL, **3**, 489–98 (1920).

	Raw batch per cent	Raw batch for 100 lbs. melted	Melted per cent	
Feldspar	49.0	62.5	62.5	
Borax	35.0	45.0	16.3 B_2O_3	
			7.45 Na_2O	
Soda ash	7.8	10.0	5.8 Na_2O	14.7
Soda nitre	3.1	4.0	1.45 Na_2O	
Bone ash	3.5	4.5	4.5	
Antimony oxide	1.6	2.0	2.0	
	100.0	128.0	100.0	
Empirical formula	0.285 K_2O	0.285 Al_2O_3	1.72 SiO_2	
	0.600 Na_2O	0.600 B_2O_3		
	0.115 CaO	0.018 Sb_2O_3	0.076 $(PO_4)_2$	

The composition of the frit is based on the assumption that such materials as feldspar, bone ash, antimony oxide, and cryolite lose no weight during melting. The method of calculation is similar to that described by Staley in his treatise on enamels for cast iron.[1]

The results of preliminary experiments and the desire to bring out clearly the effect of feldspar on fish scaling showed the advisability of working with three groups of enamels, so arranged that the feldspar remained constant in any group, the variations being made in the fluxes. The feldspar content was set at 59 per cent, 62.5 per cent, and 66 per cent, respectively, the preliminary experiments having demonstrated that these about covered the field of workable enamels. The groups shown in tables 1 and 2 have served as the basis for the work on the gray ware enamels.

TABLE 1—COMPOSITION OF MELTED ENAMELS

Material	Constant parts 59% feldspar group	62.5% feldspar group	66% feldspar group
Feldspar	59.0	62.5	66.0
Sodium oxide	10.0	10.0	10.0
Boric oxide	14.0	14.0	10.5
Fluorspar	3.5	0.0	0.0
Bone ash	4.5	4.5	4.5
Antimony oxide	2.0	2.0	2.0
Variable	7.0	7.0	7.0
Totals	100.0	100.0	100.0

[1] H. F. Staley, "Manufacture of Cast Iron Enameled Ware," *B. S. Tech. Paper*, No. **142** (1919).

Material	Amount	Enamel	Variable parts, Enamel	Enamel
Sodium oxide	7	A-20	A-1	A-16
Boric oxide	7	21	2	12
Fluorspar	7	22	3	17
Cryolite	7	23	4	18
Sodium oxide	3.5	24	6	9
Boric oxide	3.5			
Sodium oxide	3.5	25	7	19
Fluorspar	3.5			
Boric oxide	3.5	26	10	14
Fluorspar	3.5			

Additions for direct increases of feldspar

21*a*—Enamel 21 plus 5% feldspar
21*b*—Enamel 21 plus 10% feldspar
23*a*—Enamel 23 plus 5% feldspar
23*b*—Enamel 23 plus 10% feldspar

TABLE 2—BATCH COMPOSITION OF ENAMELS—WEIGHTS OF RAW MATERIALS TO GIVE 100 PARTS MELTED

Material group	59% feldspar group	Constant parts 62.5% feldspar group	66% feldspar group
Feldspar	59.0	62.5	66.0
Sodium nitrate	4.0	4.0	4.0
Soda ash	4.0	4.0	6.7
Borax	38.2	28.2	28.7
Fluorspar	3.5	0.0	0.0
Bone ash	4.5	4.5	4.5
Antimony oxide	2.0	2.0	2.0

Material	Amount	Enamel	Variable parts, enamel	Enamel
Soda ash	12	A-20	A-1	A-16
Boric acid	12.4	21	2	12
Fluorspar	7	22	3	17
Cryolite	7	23	4	18
Soda ash	6.0	24	6	9
Boric acid	6.2			
Soda ash	6.0	25	7	19
Fluorspar	3.5			
Boric acid	6.2	26	10	14
Fluorspar	3.5			

Additions for direct increase in feldspar

21*a*—Enamel 21 plus 5 parts feldspar
21*b*—Enamel 21 plus 10 parts feldspar
23*a*—Enamel 23 plus 5 parts feldspar
23*b*—Enamel 23 plus 10 parts feldspar

The various enamels were compounded by weighing up the base enamel in each group and adding to it the required amount of flux to produce the desired composition. For example, A-20 was made by weighing the raw materials listed in the 59% feldspar group (table 2), and adding to it 12 parts of soda ash. A-2 was compounded by weighing the base for the 62.5% feldspar group and adding to it 12.4 parts of boric acid. The complete batches were then mixed for melting.

For preliminary tests, the enamels were weighed in 4.5 lb. batches, mixed thoroughly by hand and by sieving. These were then melted in fire-clay crucibles in a pot furnace. An attempt was made to keep a uniform melting temperature, a number of readings with an optical pyrometer indicating a temperature of about 1170°C (2140°F).

The average time of melting was about one hour, the operation being carried to a point where the melt was as free from bubbles as possible under the conditions of crucible melting. The melts were quenched in water, dried and then ground wet in porcelain ball mills, the following mill batches being used:

Frit	1000 grams
Clay	60 "
Magnesium carbonate	5 "
Water	55 ccm.

The batches were ground for seven hours which was sufficient to permit them to pass an 80 mesh sieve.

The enamels were then applied to 2 × 3 inch plates of a 20-gauge iron, hereafter designated as Iron A (see table 4). These had been prepared by boiling in a solution of caustic soda for about 20 minutes to remove oil, then rinsed in clear water and pickled in a hydrochloric acid bath of one part acid (1.18 sp. gr. 36% HCl), to seven parts water. This gave an acid content of about 5.5 per cent.

After pickling, the plates were rinsed several times in water and were then kept under water until ready for the application of the enamels. The latter were applied by dipping, epsom salts being used as the flotation medium. The plates were then dried and were ready for firing.

A definite firing schedule was established to determine the effect of variations in firing, so that there might be a basis of comparison for various enamels under the same heat treatment. The following schedule was made broad enough to cover the range of the various enamels:

Temperature in degrees C	Temperature in degrees F	Time in minutes		
760	1400	2	4	6
820	1508	1 1/2	3	4 1/2
880	1616	1 1/4	2 1/2	3 3/4
940	1724	1	1 1/2	2

Ten samples of every enamel were made for each temperature and firing period. The plates were fired in a Hoskins electric muffle furnace and were supported on a grid of wrought iron which was left in the muffle continuously in order to keep it at furnace temperature. A platinum platinum-rhodium thermocouple enclosed in a very thin porcelain tube was placed directly over the plates and, the muffle being about 6 × 8 × 12 inches, the temperature could be regulated fairly accurately within 10°C of the accepted standard.

Effects of Variations in Composition and in Firing

The following conclusions can be drawn from this phase of the work:

(1) In a normal enamel fish scaling increased with increase in temperature or length of time of firing beyond normal firing conditions.

(2) Too low a temperature or too short a firing period produced blistering and bubbling, while high temperatures and long periods resulted in burning off of the enamel.

(3) Considering only those results in which the enamels were properly fired, the following order gives the relative effects of various fluxes in reducing fish scaling, the most effective being placed first:

a. Cryolite
b. Fluorspar
c. Sodium oxide
d. Boric oxide

(4) The burning range of the enamels is lengthened by the

following materials in the order named, the most effective being noted first:

a. Cryolite
b. Fluorspar
c. Boric oxide
d. Sodium oxide

Fusion Tests of Enamel

On the basis of the above results, it was assumed that this "fish scaling order" of the fluxes followed the relative fusibilities of the enamels, but further work has proven otherwise. Fusion tests of cones prepared from these enamels have placed the fluxing action of the materials in the following order, the first named giving the most fusible enamels:

a. Cryolite
b. Sodium oxide
c. Fluorspar
d. Boric oxide

These determinations were checked by melting small layers of

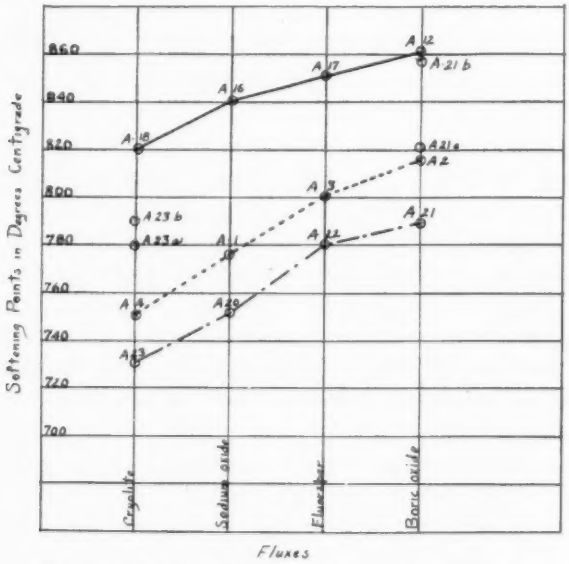


FIG. 1.—Relative fusibilities of gray ware enamels.

enamels on ground coated plates at various temperatures for periods of two minutes and noting the temperature at which the enamels fused. These temperatures, while not agreeing with the softening points of the cones, place the fluxes in the same relative position as shown in the curves, figure 1.

Effect of Variations in Smelting Procedure

To determine the effect of over- and under-smelting, the first four enamels, A-1, A-2, A-3, and A-4, of the group containing 62.5 per cent feldspar were selected. Three batches of each enamel were made and melted as described previously but with the following changes in the duration of melting. The under-melted batch was carried to the point where all the raw materials were apparently melted, no attempt being made to drive off the gases. This required on an average about 40 minutes. The medium melted enamels were melted until the gases had been driven off and the melt had become quiescent. This required on an average about 55 minutes. The over-melted enamels were held at this same point for about 15 minutes longer, giving on an average about 70 minutes. These enamels were prepared and applied, as described previously in this paper, to 2 × 3 inch plates of Iron A and a steel designated as Steel B.

The following conclusion may be drawn as to the effect of various treatments in melting:

(1) Increasing the time of melting of an enamel has apparently but slight effect on the tendency to fish scale. It must be remembered, however, that while the melts were apparently over-melted in 70 minutes, the increased effect of melting is probably not as great as that encountered in actual practice where the results tend to show that over-melting increases fish scaling, undoubtedly due to the volatilization of fluxes like sodium oxide[1] which tend to decrease fish scaling.

The effect on fish scaling of variation in the steel is very apparent in this part of the investigation since the scales on Steel B are much larger than those on Iron A.

[1] Poste and Rice, "Effect of the Degree of Smelting," THIS JOURNAL, **1**, 221–37 (1918).

A number of these gray ware enamels typical of those prone to fish scale and others free from this defect have been applied to the various steels and irons listed in tables 4, 5, 6, and 7. The general results confirm those obtained with Iron A and Steel B although there is a tendency on the part of certain stocks to develop a greater or less tendency to fish scale even when coated with the same enamels. Steels C and D, for instance, which are cold rolled strip steel, although not considered as enameling stock, show a complete freedom from the defect. It is evident therefore that further consideration must be given to the various properties of the stocks such as expansivity, chemical composition, mechanical condition, and so forth. These have been carefully studied with the results shown in the following sections.

Thermal Expansion of Enamels

The foregoing studies have indicated that composition and heat treatment of the enamel have a marked effect on fish scaling. There are variations in some of the results which undoubtedly are consequences of improper manipulation. There still remains, however, the fundamental problem of why enamels fish scale and an explanation for the variations in results obtained with various steels and irons.

Because of the nature of the defect, the most logical place to look for the solution is in the relative thermal expansivities of the enamels and stock. Tabulated values of coefficients of expansion for iron and steel usually indicate a value of 12×10^{-6} to 13×10^{-6} per °C. Empirical formulas for the enamel values in terms of composition have been supplied by Winkelman and Schott and by Mayer and Havas.[1] By using these formulas it has long been considered possible to mix an enamel which will match the stock. We are all familiar with the attempts and failures of this method. A further confusion has arisen due to the fact that different specimens of stock of practically the same expansive qualities have shown different results. With these contradictions and indefinitenesses hindering further progress, it was decided to make a comprehensive survey of the subject of

[1] Mayer and Havas, "Coefficient of Expansion of Enamels and Their Composition," *Sprechsaal*, **44**, 188 (1911).

expansion, disregarding for the time being all previous work on this phase by other investigators.

In this work the regular equipment of the Expansivity Section of the Bureau was utilized, the accuracy of which may be stated as 0.1 per cent.

For the study of the metal stocks a number of representative irons and steels were selected and strips were cut from the plates approximately one inch wide and 14 inches long. In commencing the work on enamels, specimens were prepared from both the molten frit and the enamel prepared for dipping, but no difference was observed so the work was continued on the latter alone.

The specimen rods of enamel were 14 inches long and triangular in cross section, being about $^3/_8$ inch along a side. These were prepared by drying the enamel slip, placing the resulting powder in sheet iron troughs lined with asbestos paper and melting the powder to an enamel rod in the enameling furnaces at approximately enameling temperatures. This required about five minutes, after which the troughs and contents were removed to an enameling furnace at 500°C (932°F) and cooled slowly to room temperatures.

In the expansivity furnace, the specimens were supported horizontally in quartz tubes. V-shaped rings were cut around the specimens near each end so that 2-mil annealed platinum wires could be fastened in these. Each wire, hanging through a hollow tube below the end of the specimen and extending downward through and below the furnace, had at its lower end a vane (or weight) immersed in oil in order to dampen the vibrations. Heating was effected by electric resistance coils (outside, inside, and end coils). With careful manipulation it was possible to adjust the circuits so that during an observation the specimen was at a uniform temperature within 0.1°C, from end to end.

The length changes were determined with a comparator consisting of two microscopes rigidly clamped on an invar bar at a distance from each other equal to the distance between the grooves of the specimen (30 cm.). The microscopes were so arranged that they could first be sighted on a standard-length bar kept at constant temperature, and then on the vertically suspended wires which were in the grooves at the ends of the specimen.

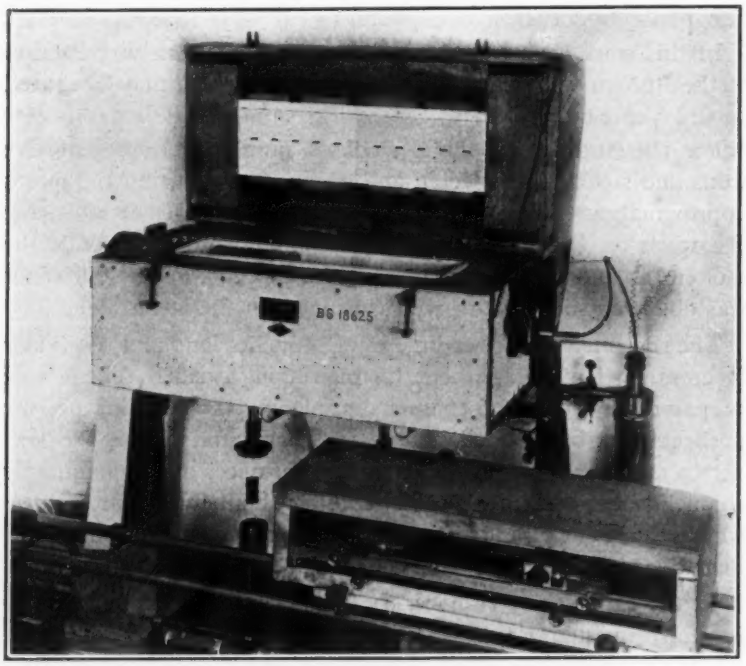


FIG. 2.—Expansivity apparatus.

The apparatus shown in figure 2 was used for this research. This figure portrays the essential method of making observations on materials. The furnace is shown with the top lifted. The traveling microscopes, which are sighted (simultaneously) on the two vertical wires hung from the specimen, are displaced to the right in order to show the construction of the tube protecting the vertical or drop wires. The left oil pot is removed to show the weight attached to the wire.

The temperatures in the furnace were determined by means of a platinum platinum-rhodium thermocouple. It had been noted that enamels became viscous on enameled plates at about 550°C (1020°F) so it was decided to make the expansion studies between room temperatures and 500°C.

TABLE 3—COEFFICIENTS OF EXPANSION × 10^6

GRAY WARE ENAMELS AND STEELS

Enamel	1. Room to 200°C	2. Room to 400°C	3. Room to 500°C	4	5	6
A-1	10.9	11.3	13.9	11.7	0.8	0.4
A-2	8.8	9.4	10.7	9.4	.6	.0
A-3	9.4	10.7	13.2	9.9	1.2	.8
A-4	9.8	11.6	13.4	11.0	1.2	.6
A-12	8.2	9.3	10.6	9.7	1.5	.4
A-16	9.4	10.1	10.8	12.0	2.6	1.9
A-17	9.1	10.2	11.9	10.2	1.1	.0
A-18	9.3	10.4	12.6	11.3	2.0	.9
A-20	10.1	10.9	13.8	11.6	1.5	.7
A-21	8.1	10.1	11.3	9.3	1.2	.8
A-21*a*	8.1	9.0	10.2	9.2	1.1	.2
A-21*b*	8.3	9.1	10.5	9.2	.9	.1
A-22	9.5	10.6	13.7	9.8	.3	.8
A-23	10.0	11.4	13.8	11.0	1.0	.4
A-23*a*	8.8	10.4	11.8	10.9	1.1	.5
A-23*b*	9.3	10.6	13.5	10.7	2.0	.1
Steel A-A	12.7	14.1	14.6			
Steel A-B	12.7	14.1	14.5			
Steel A-D	13.1	14.2	14.6			
Steel C-*hd*	12.6	14.2	14.5			
Steel C-*an*	12.9	14.1	14.8			
Steel C-*an-el* 25%	12.7	13.8	14.2			
Steel B	12.8	14.0	14.4			
Iron A	13.0	13.9	14.4			
Iron A-*el* 20%	12.7	14.0	14.6			

(1, 2, 3) Observed values for coefficients of expansion of enamels and steel from cooling curves.

(4) Calculated values of coefficients of expansion from Havas and Mayer's values.

(5) Calculated values compared with Bureau observation—room to 200° C, differences.

(6) Calculated values compared with Bureau observation—room to 400° C, differences.

The values for the various steels and enamels studied are given in table 3, as well as the figures computed from the values given by Havas and Mayer[1] for various oxides. In figures 3, 4, and 5 are shown the curves for the various enamels as compared with steel.

In these curves the temperatures are plotted as abscissas and the expansions per unit length as ordinates. The expansion

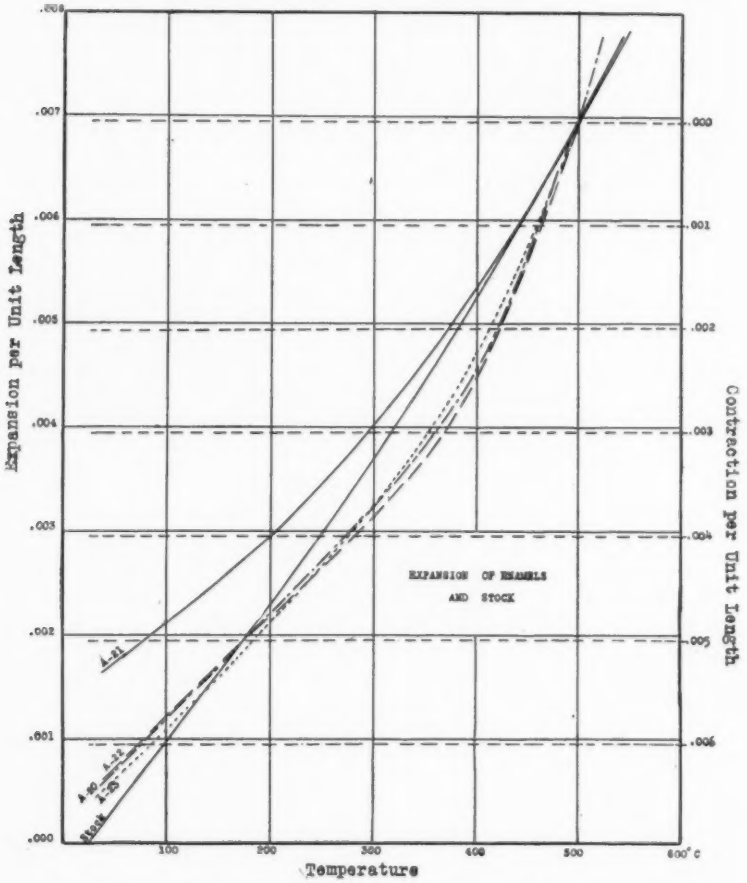


FIG. 3.—Expansion of enamels A-20 to 23 and stock matched at 500°C.

[1] *Loc. cit.*

for the stock was plotted first, and, for the reasons stated above, the enamel expansions plotted to agree with the stock at 500°C. The actual total expansion of stock per unit length, from room to any higher temperature, may be read directly at the left of the curve. In getting the actual expansions of the enamels between any two temperatures it will obviously be necessary to take the difference of the two readings at the left corresponding to the respective values of the temperature interval.

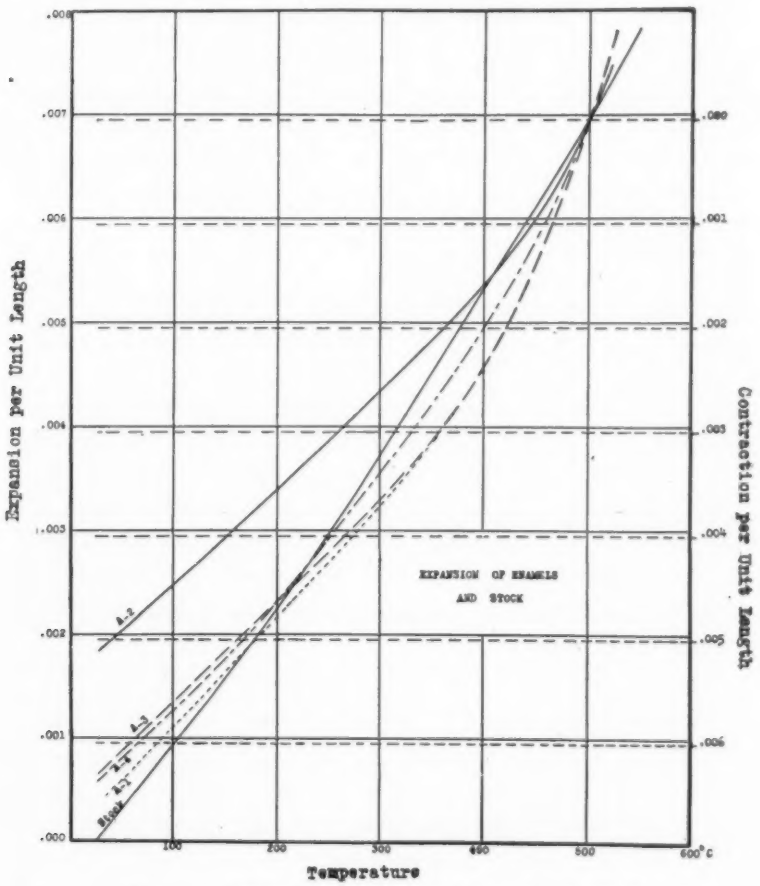


FIG. 4.—Expansion of enamels A-1 to 4 and stock.

A brief discussion of the above is appropriate at this time. Heat and mechanical treatments failed to modify the expansivities of these stock steels and irons, which is contrary to the results in cast iron enameling where growth of the iron casting is encountered as a result of heating. The values of the coefficients of expansion of the various stocks in table 3 will be found so nearly the same that an extended discussion is not necessary at this

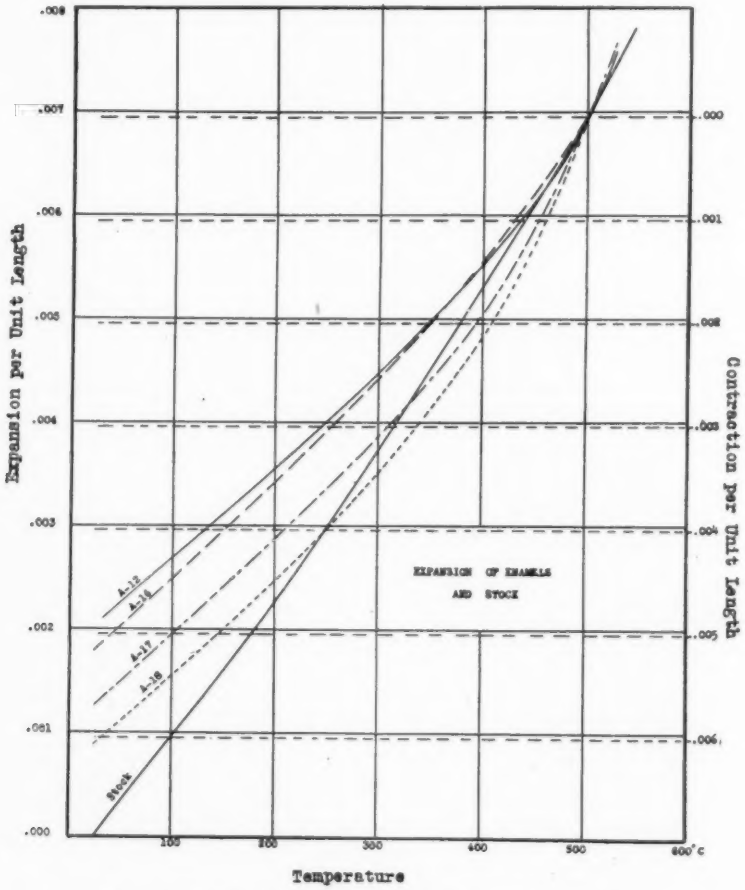


FIG. 5.—Expansion of enamels A-12 to 18 and stock.

time. The letters (*hd*) after specimen C refer to hard cold rolled material. Similarly (*an*) indicates annealed and (*el*) indicates elongated or stretched in the tensile apparatus.

From a study of these values it is evident that cold rolling, annealing, stretching, and so forth, have only a negligible effect, if any at all, on the expansivities of stock. Furthermore, the general character of the heating and cooling curves obtained in these tests show that no permanent changes were introduced in the material (so far as expansivity is concerned) since they all returned to their original lengths after testing.

The enamel expansions are lower than those for steel although both increase with temperature; the former, however, increasing faster than the latter. As has been stated previously, the enamels become viscous above 500 or 550°C. At these temperatures we assume that they adapt themselves perfectly to all changes in the stock. Upon cooling there is some temperature at which the enamel becomes rigid and offers resistance to inequalities in contraction. This point has been selected as 500°C, although there is no objection to changing it to a few degrees higher or lower if desired. Accordingly all curves have been set to match at 500°C at which temperature there is an absence of all strains. The deviations of these curves at lower temperatures indicate the corresponding strains to be expected. In most instances the enamels have contracted faster on initial cooling (Enamels 1, 3, 4, 17, 18, 20, 22, 23) and are tending to compress the stock; however, before reaching room temperatures the enamels have slowed up and at normal temperatures all are being compressed by the stock.

Perhaps a more logical method will be to consider the ordinates of the curves referred to contractions rather than expansion. The dotted horizontal lines are arranged to indicate contraction on cooling from the solidification temperature. In figures 3, 4, and 5, this temperature has been taken as 500°C, in the remainder as 450°C. The values at the right of these curves refer to the actual contractions of all specimens on cooling below the fiducial temperature. For example, in figure 3, the contractions on cooling from 500°C to 100°C are as follows: A-21 contracted 0.0048 of

the length at 500°C and the stock contracted 0.0059 of the length at 500°C. The difference between the two contractions gives the expected strain at 100°C, *i. e.*, 0.0011. These values may be used in any system of units, *e. g.*, a 1 meter specimen of A-21 at 500°C if free to contract will have a length of 0.9952 meter at 100°C; or a one inch specimen will have a length of 0.9952 inch, and so forth. In practice we may expect a compromise and in reality that the enamel will be compressed below the 0.9952 value due to the greater tendency for contraction of the iron (to a length of 0.9941). Similarly the iron may never reach this lower value but may stop at a higher value due to the restraining effect of the enamel. Table 3 gives the complete assemblage of all values from the series A enamels and various steels and irons. All values in table 3 are expressed as millionths per unit length, per degree C.

Manifestly those enamels most widely separated from the stock at room temperature, A-12, A-21, should have the greater tendency to scale and those more nearly agreeing with stock at this temperature (A-1, A-4, A-20 and A-23) should exhibit a lesser tendency. These conclusions are borne out by the enameled specimens. It should be pointed out that while no enamel matches the stock absolutely, enamels do adhere satisfactorily and that this adhesion is due to the strength and elasticity of the enamel, and to the union of enamel and stock (either chemical or mechanical) and that by properly treating the stock by mechanical means (as will be shown later) it is possible to cause practically any enamel to adhere to any stock, regardless of the inherent strains set up. Unless these strains are later released by annealing as will be explained, the ware should not be expected to stand up under severe treatment.

As previously stated, the empirical formulas of Mayer and Havas are supposed to indicate the expansion of the various batches on the basis of chemical composition. While it is understood that the rate of expansion increases rapidly with temperature (see figures 3, 4, and 5) and that these values do not give complete information, still it was thought desirable to attempt to arrange their values to indicate, if possible, correct expansion at

some one temperature. By comparing the average values for twelve different enamels, it appears that the Mayer and Havas results most nearly indicate expansions for the range from room temperature to 400°C. The original articles, however, show that the values are taken from determinations over the range, room to 100°C. For comparison only, they are arranged near our column, room to 400°C. In some instances the empirical values run above and in other below the experimental. The extreme variation of these is greater than the widest variation for all twelve enamels. It so happens for this set of enamels (excluding the specials 21*a*, 21*b*, 23*a*, 23*b*) that, if we should state that all enamels will have expansions exactly equal to 10.6×10^{-6} (regardless of composition or otherwise) over the range, room temperature to 400°C, then the variations or errors would be less than those obtained by using Mayer and Havas values. A further question is raised as to the wisdom of ever using these values, as is shown by the expansion values observed for enamels 21, 21*a*, 21*b*, and 23, 23*a*, 23*b*. The addition of 5% feldspar to A-21 and 23 gives the 21*a* and 23*a* batch and the addition of 5% more, the 21*b* and 23*b* batch. The feldspar linear coefficient is 8.3×10^{-6} whereas the A-21 enamel computes 9.3×10^{-6} and the A-23 is 11.0×10^{-6}. In each case the addition of 5% feldspar might be expected, according to Havas, to reduce the coefficient and further, the latter enamel (23) should reduce more than the former (21) since its expansion computes 11.0×10^{-6} against 9.3×10^{-6}. Observation will show the values reduced, but in reverse order; number 21 from 10.1 to $9.0 = 1.1$ and number 23 from 11.4 to $10.4 = 1.0$. The addition of the next 5% feldspar might be expected to give similar (perhaps slightly less) reductions in coefficients; unfortunately it does not, but produces a definite increase in each case. This reduction and later increase may perhaps be explained on some such basis as follows: feldspar may tend to reduce all coefficients toward a value of 8.3×10^{-6} when mixed in batches of material wherein there is an excess of certain other constituent, but when the excess of this certain other constituent is overbalanced by an excess of feldspar the reverse is true. The authors are conscious of the fact that values over a range, room to 100°C, have been applied for a range,

room to 400°C. The range, room to 100°, would have indicated far greater variations and as stated before, the application was made at the point of greatest advantage for the Mayer and Havas values. A further defect in these tables is the fact that they give only a single value for the coefficient whereas the values for all the above specimens increase with increasing temperature. In a later paper, this phase will be treated more fully and an additional reason given, showing why it is impossible to secure relative values from these empirical tables.

We are forced to conclude that there is very little significance to be attached to these formulas of Mayer and Havas and that although they may appear to give results in some cases, there is always the uncertainty of knowing which cases are typical and which are exceptional.

The following conclusions may be drawn from this work:

(1) The coefficients of expansion and contraction are very nearly the same within the temperatures given for the various irons and steels used in this work. Therefore, the variations in fish scaling as evidenced in various steels can not be due to variations in the expansion and contraction of the various steels.

(2) Expansion of steel is greater than that of enamels by 3 to 40 per cent.

(3) The various constituents of the enamel have varying effects on the coefficient of expansion of the enamel.

(4) The values for the coefficients of the enamels between room temperatures and 200°C run from 20 to 40 per cent lower than those for steel.

(5) The coefficient of the enamels increases very rapidly above 200°C.

(6) The coefficient values computed from the Mayer and Havas' table are not accurate. Further, this method gives only a single value whereas it is evident that the coefficient is not constant for the various temperatures.

(7) If held at a constant temperature, between 200 and 300°C the enamels show shrinkage.

Effect of Annealing Enamels

Assuming then that fish scaling is due to the difference in the contractions of the steel and enamel and also bearing in mind further that enamels show shrinkage on slow cooling, annealing or slower cooling of the enameled ware should decrease or even eliminate fish scaling.

A study was made on small plates and stamped bowls coated with enamels A-21 and 23, half of the pieces being cooled normally and the other half placed in an annealing furnace at 500 °C and allowed to cool slowly in approximately four hours to room temperature. It was assumed that this method would allow the enamel to shrink and more nearly match the steel coefficient. A further advantage would be that it would allow the steel to cool and contract at the same time that the enamel contracts, whereas, if allowed to cool suddenly, the protected steel will be hotter than the exposed enamel, and after the enamel becomes rigid will have a longer range of temperature to travel with a larger coefficient, thus intensifying the strain between enamel and steel.

It was clearly demonstrated that annealing of the enameled ware eliminated fish scaling and that the normal air-cooled ware did fish scale, especially with the high boric oxide enamel A-21, which has a low coefficient. The annealed ware has been examined some eight months following the test and there are no indications of scale while the normal pieces scaled within 24 hours following firing.

This study is of value from two viewpoints. First, it demonstrates clearly the value of the coefficient of contraction theory, and secondly, while annealing may be objected to commercially because of the extra cost it entails under present conditions, it points to a decided advantage in the use of continuous enameling furnaces of a tunnel type where provision will undoubtedly be made for cooling the ware slowly as it emerges from the firing zone.

Chemical Compositions of Steels and Irons

When it was shown by thermal expansion studies of the steel and iron stock that many variations in their enameling properties could not be laid to variations in the coefficients of expansion,

it was deemed advisable to make a study of the chemical constituents most likely to affect the enameling qualities. The compositions of the various stocks were as follows:

TABLE 4—ANALYSES OF VARIOUS ENAMELING STOCKS

Stock	Results of analyses in per cent C	Mn	P	Si	S	Cu	Results in enameling
Steel C*...	0.08	0.37	0.020	0.001	0.070	0.022	No fish scaling
Steel D**..	0.066	0.34	0.011	0.002	0.052	0.033	No fish scaling
Iron A.....	0.014	0.009	0.006	0.005	0.025	0.056	Some scaling
Steel E....	0.060	0.36	0.020	0.030	0.056	0.082	Considerable scaling
Steel B....	0.055	0.33	0.008	0.002	0.026	0.270	Badly scaled

* C, hard cold rolled strip steel

** D, dead soft cold rolled strip steel

A review of these analyses and enameling results seemed to bring out very decidedly the fact that fish scaling was intimately related to the copper content of the steel or iron used as the base for the enamel. However, these stocks were comparatively low in copper with the exception of Steel B and it was, therefore, decided to experiment on other enameling steels which would be typical of those containing higher contents of copper. The tests were, therefore, continued on enameling steels of the following composition:

TABLE 5—ANALYSES OF STEELS

Stock	Gauge	Results of analyses in per cent C	Mn	P	Si	S	Cu	Results in enameling
A-A Open hearth....	20	0.075	0.41	0.015	0.010	0.040	0.132	Good
A-B Open hearth....	16	0.075	0.40	0.014	0.010	0.039	0.136	Poor
A-C Open hearth....	24	0.065	0.37	0.035	0.010	0.042	0.148	Fair
A-D Open hearth....	20	0.120	0.34	0.075	0.010	0.041	0.192	Bad
A-E Bessemer.....	20	0.090	0.35	0.080	0.009	0.028	0.160	Fair

These steels were enameled, in the regular method outlined, with Enamels A-21 and 23. It was soon noted that while the gauge has some effect on fish scaling, the heavier gauge steel apparently showing most scale, there was no definite increase of scale with increase in the copper content of the steels. The series was hardly systematic enough, however, to give conclusive proof so an attempt was made to procure a series of steels and irons with increasing copper content from small to large amounts. This resulted in a study on the stock of the following chemical composition:

TABLE 6—ANALYSES OF IRON SHEETS—COPPER SERIES

No.	S	P	C	Mn	Cu	Enameling results
2651	0.017	0.005	0.010	0.012	0.018	Many scales
2636	0.026	0.006	0.014	0.015	0.060	Very few fine scales
2641	0.025	0.008	0.012	0.018	0.090	Few fine scales
2637	0.025	0.006	0.012	0.018	0.190	Few scales
2640	0.024	0.010	0.010	0.018	0.263	Many scales

TABLE 7—ANALYSES OF STEEL SHEETS—COPPER SERIES

No.	S	P	C	Mn	Cu	Enameling results
2638	0.029	0.008	0.11	0.410	0.072	Large number of fine scales
2642	0.020	0.011	0.08	0.358	0.094	Large number of fine scales
2643	0.030	0.010	0.11	0.408	0.136	Many large scales
2639	0.020	0.010	0.09	0.388	0.316	Many large scales

It was soon made apparent that fish scaling was not directly related to copper content and that the results of the systematic study did not bear out the earlier conclusions drawn in this connection for there was still evident widely differing results in the amount of fish scaling on the various steels.

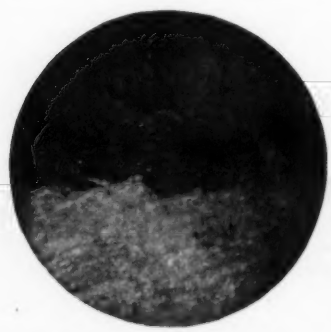
It is sufficient to state that variations in enameling results as regards fish scaling do not appear to be due to the chemical composition of the stock within the ranges studied (and these steels and irons all fall within the limits prescribed for enameling stocks) but rather to their mechanical treatment as will be shown later in this work.

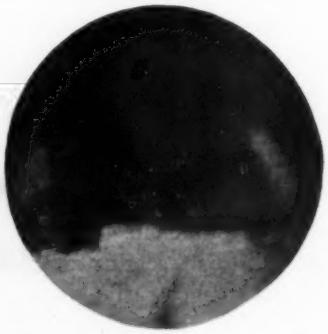
Mechanical Treatment of Enameling Stock

While the foregoing results show that fish scaling may be prevented by selecting an enamel of proper expansivity, at the same time they indicate that other factors have effects which can not be ignored. For example, Enamel A-21 adheres to Steel C but does not adhere to Iron A nor A-B and D Steels. Enamel A-23 gives very little scaling with any of the stocks; one reason, at least, being the nearer match in expansion of Enamel A-23. Now considering expansivity only we should conclude that if Enamel A-21 will adhere to Steel C then it should likewise adhere to Iron A which has practically the same expansivity as Steel C.

The other factors which must be considered to account for the numerous failures of Enamel A-21 are lack of ability to stand up under compressive stress or poor union of enamel and stock.

In many instances, the failure appears to be due to the brittleness or weakness under compressive stress. The form of the scale itself being of varying thickness from full depth at one part to a sharp edge at the outer part at once suggests a compressional failure. It might appear that the roughness or porosity of the stock was sufficient to allow the enamel to penetrate and interlock (figure 6) and that the scale snapped off the stock from a very small smooth area only (figure 7), but spread as it approached the outer enamel surface, giving the scale a form not greatly dissimilar to those of compressive failure specimens.

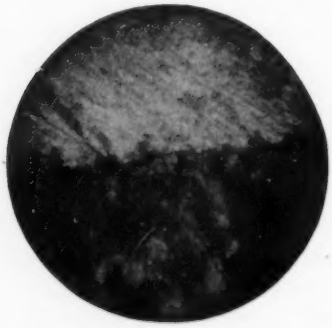




FIGS. 6 and 7 from adjacent sections. Same edge of enamel showing in both views.

FIG. 6.—Cross section of fish scale, ×215. Where enamel adhered.

FIG. 7.—Cross section of fish scale, × 215. Where enamel scaled.



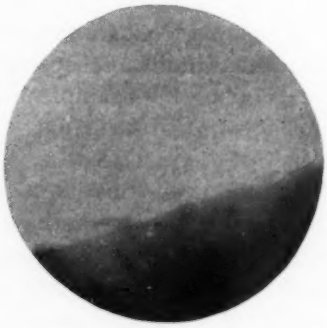


FIG. 8.—Cross section of enamel, ×215. Steel etched away.

FIG. 9.—Cold rolled steel and enamel, ×215.

When larger areas of enamels chip away from the steel, immediately on cooling of the fired ware, failure is undoubtedly due to the lack of union between iron and enamel, and the phenomenon is to be differentiated from fish scaling. Failures of this type have been traced to imperfections in cleaning, pickling, coating of the stock, or similar defects.

All enamelers are familiar with the effects of shapes or patterns in vessels and have also noticed that the sides of a spun vessel do not scale as readily as the untreated bottom surfaces. Tests were made to determine what effects could be attributed to a possible difference in the rate of cooling of protected, and unprotected flat and curved surfaces, by carefully annealing the pans and then enameling. Apparently annealing of the stock had no effect on the fish scaling.

This process of elimination practically forces the theory of mechanical adhesion upon us as the determining factor in this special case. To verify the theory that greater working of the metal was responsible for lack of fish scaling on the sides of drawn and spun vessels, several strips of steel and iron were stretched to 10 per cent elongation. The strips were so clamped that only half of the strip was stressed, so that the comparative effects on fish scaling could be determined under exactly the same conditions.

The plates were cleaned and pickled in the regular way and Enamel A-21 was applied, the latter being typical of an enamel prone to fish scale. It was found in every case that the stressed portion was absolutely free of scale while the normal portion fish scaled, the line of demarcation between the two portions being very sharp in this respect. This effect is unquestionably due to the mechanical treatment of the iron. Expansion tests of both stretched and cold rolled specimens of steel and iron are recorded in table 3 (see Steel C, elongated, Iron A, elongated, and Steel C, hard), from which we see that this treatment has not changed the rate of expansion appreciably.

In casting about for some true explanation of this variation in properties of the steels, use was made of the microscope in studying the surfaces of the metal since it was believed that the

cause for variations would lie in the variations of surfaces. It was noted in these latter studies that the surfaces of Steels C and D (which steels had never developed scaling) were very smooth and regular in structure. It was presumed that the fact that these steels were cold rolled had possibly some effect on their enameling properties and samples of the various steels were given a cold rolling that decreased their thickness by about 0.015 of an inch, and at the same time polished the surface. These steel specimens when enameled gave perfect results and no fish scaling developed.

The results with cold rolling of iron were, however, not as promising. Although the development of scale was materially decreased on the treated iron, there was not the complete elimination of scale which it had hoped would result. It is evident that there is some difference in the effect of cold rolling on steels and on irons which must be explained.

It might be assumed that cold rolling had carried the metal beyond its elastic limits and had introduced certain permanent molecular changes in the metal beneficial from an enameling standpoint. That this is unlikely is shown by the fact that the same results were obtained in enameling regardless of whether the plates had been annealed or simply cleaned in a caustic solution following cold rolling and previous to pickling for enameling purposes.

Further, cold rolled specimens tested in the expansivity furnaces and therefore heated over a period of about 20 hours up to 625°C, at which temperature they were held constant for about two hours and then cooled slowly to room temperatures, behaved exactly as the normal rolled stock.

In mechanically treating the metal, either changes are produced in the surface which permit the enamel to combine with the material chemically or mechanically, or the elastic properties of the stock are so modified that the enamel is no longer crushed in cooling. Doubtless all factors play a salutary part. However this may be, the answer or solution by this method is the same regardless of the theory and is to treat mechanically the stock by stretching, cold rolling, spinning, shaping, or other means whereby all parts of the article are given the equivalent of the above.

In the preliminary microscopic studies of these mechanically treated samples, the ordinary methods were resorted to, that is, examination up to 100 magnifications of cross sections and surfaces. These magnifications proved unsatisfactory.

It was therefore decided to make some studies of the stocks at various magnifications from 200 to 2,000 diameters. On many specimens there is apparent under these magnifications a result of rolling or stretching which may account for its beneficial effect on the enameling properties and which may also account for the limited effect noted in the iron stock.

There has been noted in the case of some of the enameled cold rolled steels a rolling over of the tops of the peaks on the surface of the metal into the minute cavities on the surface in the direction of rolling, especially when examined under the high magnifications and perpendicular to the surface. The enamel, in melting, apparently flows back under these overhanging projections of metal and thus retains its grip on the latter in spite of the strain under which the enamel is compressed, because of the difference in expansion. Attempts are being made to reproduce such a structure artificially and in an exaggerated condition. The preliminary results of enameling such stocks are very encouraging.

In the case of the cold rolled iron, this broken cross section is not present to such marked degree. The surface has a more regular arrangement somewhat similar to that of normal steel. This is undoubtedly due to the greater ductility of the iron allowing the excess metal to be rolled down and united in the cavities, thus tending to nullify the beneficial effects of cold rolling noted in the case of the steels. In the stretched iron and steel, we should expect numerous cavities to be formed or opened up into which the enamel penetrates, which would account for the reduced fish scaling in the stressed iron and steel.

This broken structure was visible at 100 magnifications on the earlier stretched samples of steels and irons but, since the cold rolled steels C and D, at the same magnification, gave a very smooth appearance of surface, the value of the findings was consequently discounted at that time.

The microscopic studies of some sections of enameled iron and steel are shown in figures 6–9. Photographs of a specimen of steel partially cold rolled and enameled are shown in figure 11, while figure 10 shows a specimen of partially stressed steel which has

FIG. 10.—One-half of a steel strip stressed and enameled. Left half (N), normal; right half (S), stressed.

FIG. 11.—Strip, cold rolled and enameled. Left half (N), normal; right half (CR), cold rolled.

been enameled. In these there is apparent the sharp line of demarcation between the normal and the mechanically treated sections. The greater part of the scaling on the normal ends developed within 24 hours after enameling and these specimens were enameled about eight months previous to photographing. In the stressed section, a single scale is shown in the portion receiving the least stressing, since the specimen as photographed is one-half of the strip which was originally stretched.

Part II. Ground Coat Enamels

The second part of this investigation has been devoted to the study of ground coats in order to determine whether the general conclusions drawn from the study of gray ware would apply to three coat enamels.

An average composition was selected from the compositions of three commercial enamels, having various degrees of refractoriness and working properties but all giving good commercial ware. They are as follows in melted weights:

	A	B	C
Boric oxide	13.5	14.0	18.1
Feldspar	27.5	35.6	43.0
Quartz	34.7	25.4	21.6
Sodium oxide	11.6	15.8	11.6
Fluorspar	6.1	7.6	2.9
Manganese oxide	4.9	1.3	1.4
Nickel oxide	1.2	....	1.0
Cobalt oxide	0.5	0.3	0.4
	100.0	100.0	100.0

The average enamel selected for the work was as follows:

Constant	
Feldspar	27
Quartz	21
Boric oxide	12
Sodium oxide	10
Fluorspar	0
Cryolite	0
Cobalt oxide	0.5
Manganese dioxide	1.5
	72.0
Variable	
Refractories	14.0
Fluxes	14.0
Total	100.0

With this composition as a basis the following three series shown in table 8 were outlined, an attempt being made to show the effect of varying the refractories as well as the fluxes as had been done in the study of the gray ware enamels. Ground coats H-1 to H-7 comprise a series with high content of feldspar showing variations in the fluxes. Group H-8 to 14 is a high quartz series and H-15 to 21 is a mean between the high quartz and high feldspar with similar variations in fluxes. The batch compositions are shown in table 9.

These ground coats, weighed in 4.5 lb. batches, were mixed thoroughly and then melted in crucibles in a crucible furnace. The time varied with the fusibility of the frit but averaged from 45 to 50 minutes. The frit in each case was chilled in water and then ground in porcelain ball mills with the following additions:

Frit	1200 gms.
Johnson Porter clay	72 gms.
Borax (in solution)	18 gms.
Water	500 cc.

The time required for grinding averaged 12 hours but in this case it appeared that the time for grinding depended somewhat on the composition, the more fusible enamels requiring less time.

TABLE 8—PERCENTAGE COMPOSITION OF GROUND COAT FRITS

Constant part ingredients	Feld-spar	Quartz	B_2O_3	Na_2O	CaF_2	Cryolite	Ox. of cobalt	Ox. of manganese
Constant part % ingredients melted	27	21	12	10	0	0	0.5	1.5
No. of ground	Variable melted parts added to above constant portion							
H-1	14	..	7	..	7	..		
H-2	14	..	..	7	7	..		
H-3	14	..	..	..	7 + 7	..		
H-4	14	..	..	..	7	7		
H-5	14	..	7	..	..	7		
H-6	14	..	..	7	..	7		
H-7	14	..	..	..	..	7 + 7		
H-8	..	14	7	..	7	..	Constant	Constant
H-9	..	14	..	7	7	..		
H-10	..	14	..	..	7 + 7	..		
H-11	..	14	..	..	7	7		
H-12	..	14	7	..	..	7		
H-13	..	14	..	7	..	7		
H-14	..	14	..	..	..	7 + 7		
H-15	7	7	7	..	7	..		
H-16	7	7	..	7	7	..		
H-17	7	7	..	..	7 + 7	..		
H-18	7	7	..	..	7	7		
H-19	7	7	7	..	..	7		
H-20	7	7	..	7	..	7		
H-21	7	7	..	..	..	7 + 7		

TABLE 9—BATCH COMPOSITION OF GROUND COATS FOR 100 PARTS MELTED

Constant portion ingredients	Feldspar	Quartz	Borax	Boric Acid	Soda Ash	Sodium Nitrate	Fluor-spar	Cryolite	Cobalt Oxide	Manganese Oxide
Batch weights constant portion	27	21	32.7	——	5.0	4.9	——	——	0.5	1.5
No. of ground	Batch weight of variable parts added to above constant part									
H-1	14	..	..	12.4	..		7	..		
H-2	14	..	..	....	12		7	..		
H-3	14	..	..	....	..		14	..		
H-4	14	..	..	....	..		7	7		
H-5	14	..	..	12.4	..		..	7		
H-6	14	..	..	....	12		..	7		
H-7	14	..	..	....	..		..	14		
H-8	..	14	..	12.4	..	Constant	7	..	Constant	Constant
H-9	..	14	..	....	12		7	..		
H-10	..	14	..	....	..		14	..		
H-11	..	14	..	....	..		7	7		
H-12	..	14	..	12.4	..		..	7		
H-13	..	14	..	....	12		..	7		
H-14	..	14	..	....	..		..	14		
H-15	7	7	..	12.4	..		7	..		
H-16	7	7	..	....	12		7	..		
H-17	7	7	..	....	..		14	..		
H-18	7	7	..	....	..		7	7		
H-19	7	7	..	12.4	..		..	7		
H-20	7	7	..	....	12		..	7		
H-21	7	7	..	....	..		..	14		

These were applied to a number of steels, the sample plates being 2 × 3 inches and of 16, 20 and 24 gauge. The steel was prepared by cleaning in an alkaline bath and pickling in hydrochloric acid. The plates were then rinsed in water and the remaining acid neutralized in a weak soda-ash bath.

Enamels were applied by dipping, additional borax being used as a flotation medium when necessary.

In order to obtain the effect of various temperatures on fish scaling, each of the ground coats were fired on six plates according to the following schedule:

Degrees C	Minutes
800	$2^1/_2$
850	$1^3/_4$
900	$1^1/_4$

Firing according to this schedule gave to all appearances, correctly fired enamels. Half of these plates were then coated with a standard white enamel of the following composition:

Frit		Mill	
Borax	500	Frit	100
Feldspar	640	Clay	5
Quartz	360	Tin oxide	7
Soda ash	80	Magnesia	$^1/_4$
Cryolite	240	Water	50
Soda nitre	60		
Antimony oxide	40		
Fluorspar	80		
Total	2000		

The general results on the ground coat enamels are in general accord with those of the gray ware studies. For example, we find in a study of the data that the enamel constituents arrange themselves in the same order as affecting fish scaling, that is, cryolite is a superior flux to fluorspar, boric acid is an exceedingly poor flux from the standpoint of fish scaling, and soda and cryolite are much alike in their beneficial effects. It is to be noted further in this work that feldspar is apparently superior to flint.

Of the 21 enamels only one, H-6, has not developed fish scaling under any condition. This approaches very closely a type of commercial ground coat except that cryolite replaces the usual amount of fluorspar present in ground coats. It is to be noted further that the corresponding enamels in the quartz as well as in the medium-quartz medium-feldspar series (H-13 and H-20), are the best in these respective series and approach the excellent qualities of H-6. Boric oxide as in the case of the gray ware enamels is harmful from the standpoint of fish scaling. It is to be noted that better results are obtained with ground coats H-1 to 7, followed in order by H-15 to 21 and then H-8 to 14. This is undoubtedly due to the fact that the first group is highest in feldspar which we would expect to give tougher enamels in the range of compositions listed and is further evidence that the strength of the enamel is a factor in the tendency to fish scale.

The results of the expansivity studies confirm the conclusions from similar studies of the gray ware enamels and give further proof of the accuracy of our basic reason for the phenomenon of fish scaling. The coefficient values shown in tables 10 and the expansivity charts showing cooling curves for Enamels H-1 to 14, (figures 12 and 13) as compared with and matched to steel at 450 °C, make this evident. It will be recalled that the gray ware enamels were matched with the stock at 500 °C on the basis of tests

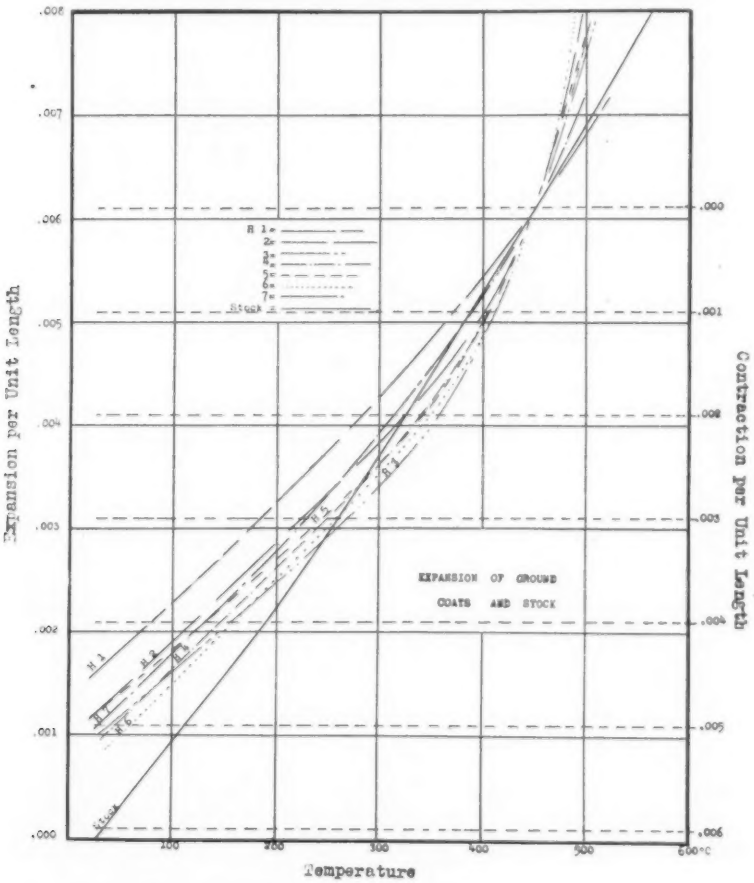


FIG. 12.—Expansion of ground coats H-1 to 18 and stock.

which showed that the gray ware enamels became viscous at approximately 550°C. It was found, however, that the ground coats softened at about 500°C and it was therefore necessary to lower the assumed temperature for initial rigidity of enamel and to fit the stock and grounds at 450°C. The following general conclusions can be drawn from the expansivity studies:

(1) Feldspar, replacing corresponding amounts of flint as a refractory, gives higher values for the expansion coefficient than the flint.

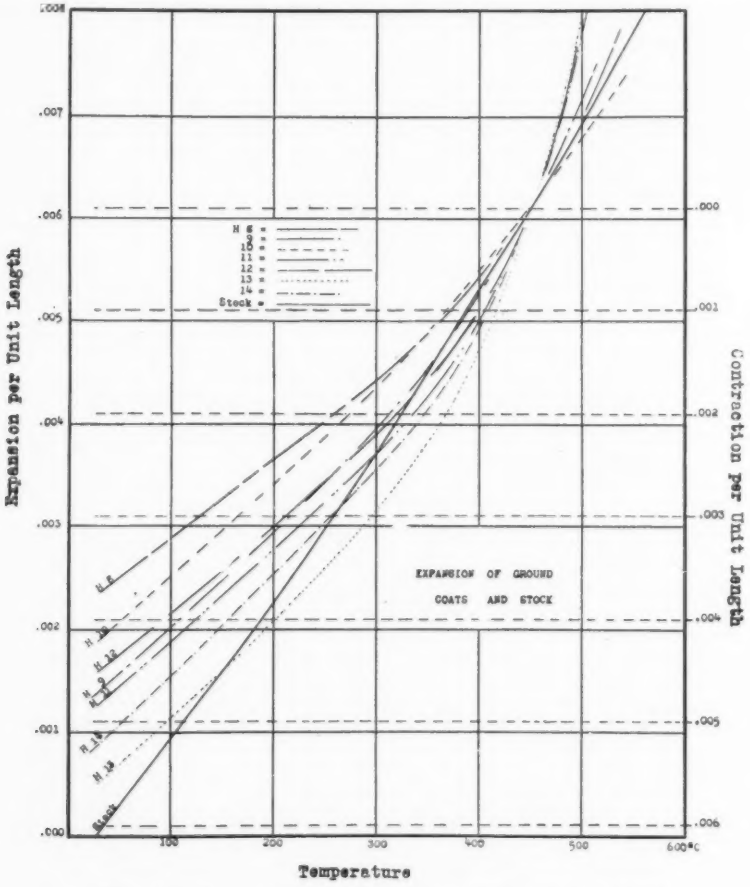


FIG. 13.—Expansion of ground coats H-8 to 14 and stock.

(2) Cryolite gives higher values on the average than fluorspar.
(3) Boric acid gives the lowest values.
(4) Sodium oxide and cryolite combinations give the highest values followed by that for cryolite alone.

The fusion points of these ground coats place the various fluxes in their same relative order as regards fluxing value (figure 14), as observed for the gray ware enamels. The cone method of determining fusion points was not applicable to the ground coats

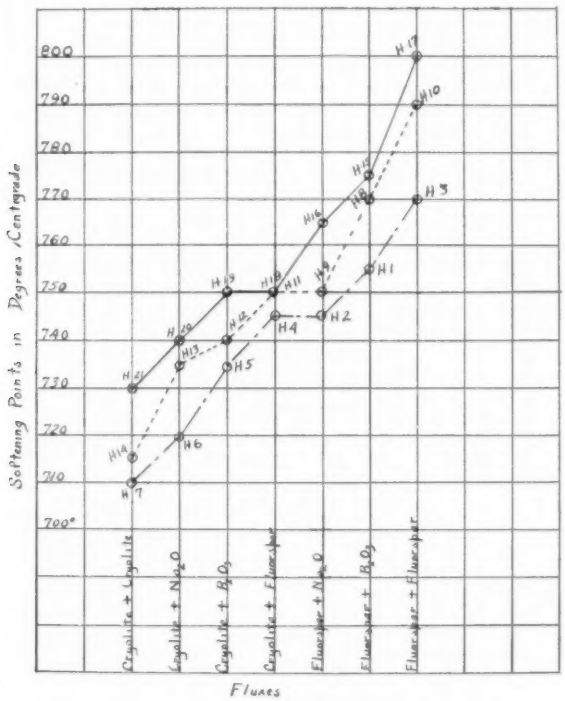


FIG. 14.—Relative fusibilities of ground coats.

as the fluxes separating out from the refractories tended to give erratic results. These softening points were, therefore, determined by placing pats of enamel on a plate and heating for two minutes at various temperatures.

The results of tests of shape of ware, annealing of enameled ware, treating of the steel, and so forth, have all corroborated the results obtained with gray ware enamels so it would appear that the conclusions can be applied generally to sheet steel enamels.

TABLE 10—COEFFICIENTS OF EXPANSION × 10^6. GROUND COAT ENAMELS AND STEELS

Ground	Room to 200°C	Room to 400°C	Room to 450°C
H-1	9.2	10.3	10.5
H-2	9.4	10.3	11.5
H-3	8.4	10.4	12.1
H-4	9.7	10.9	12.3
H-5	8.3	10.0	11.4
H-6	9.7	10.9	12.6
H-7	9.8	11.2	12.5
H-8	7.5	8.4	8.9
H-9	8.9	10.3	11.2
H-10	8.8	9.5	10.0
H-11	8.8	10.3	11.5
H-12	8.2	9.4	10.7
H-13	9.1	11.5	13.3
H-14	9.5	10.8	12.3
Av. Steel	12.8	14.0	14.2

CORDS AND SURFACE-MARKINGS IN GLASSWARE[1]

By F. E. Wright

ABSTRACT

In the manufacture of glassware it is important to distinguish between surface-markings and cords, both of which are serious defects and detrimental to quality. To do this immerse the piece of glass under test in a liquid of the same refringence and sight through liquid and glass toward a distant light. Under these conditions surface-markings disappear altogether. Cords, on the other hand, stand out more distinctly than before.

The relative refringence of a cord compared with that of the adjacent glass can also be determined at the same time. For ordinary crown glasses monochlorbenzene is suggested as an immersion liquid. To lower its refractive index add benzene; to raise it add carbon bisulfide or monochlornaphthalene.

Cords are unwelcome guests in glassware because they appear even to the casual observer as flaws and blemishes in otherwise clear glass. Glass intended for the better grades of jars and tumblers, for chemical ware, electric lamp bulbs, lamp chimneys, and the like should be free from defects of this sort. To the manufacturer their presence may mean discard of the finished article and financial loss; they signify to him a fault in manufacture, such as inadequate mixing of the batch, pot or tank-wall solution, or improper furnace control. They cannot be removed by any subsequent manufacturing operation after the glass has left the melting furnace. Cords are the trails left by currents of material of slightly different chemical composition within the molten glass. To the eye they appear like cords, strings, threads, ribbons, veins, or streaks of colorless material suspended in the glass; hence the variety of names used to describe the different types of striae.

Optical effects similar to those produced by striae may also result from the presence of faint markings or irregularities on the surfaces of the finished glass article. Under certain conditions these markings may become sufficiently serious to cause rejection of the finished article.

[1] Received April 11, 1921.

It is important for the factory foreman to distinguish between cords and surface-markings so that in a given case he can diagnose the trouble correctly and then apply the proper remedy. The purpose of this note is to describe simple methods for the diagnosis of these defects in glassware; in particular to distinguish between surface-markings and striae or cords; and, in the case of cords, to ascertain their refringence relative to that of the enclosing glass and thus to ascertain their probable composition.

In the manufacture of glassware the ordinary factory procedure is to draw from the pool of molten glass within the melting furnace a sufficient quantity of glass on the end of a blow-iron or punty, and, while the glass mass is still hot, to blow, press, or mould it into the desired shape. If on removal from the furnace the glass is too cold and too viscous, the corrugations and indentations on the surface of the ball of molten glass on the end of the blow-iron are not entirely effaced by flow, with the result that during the blowing or pressing operations these surface irregularities persist and are drawn out into fine thread and ribbon-like surface-markings which may resemble cords. They are less serious from a glass maker's standpoint than are cords because they can ordinarily be eliminated by simple means.

The obvious remedy for surface-markings is to increase the liquidity of the melt either by raising its temperature at the point where it is withdrawn from the furnace or by changing the composition of the batch so that at the given temperature the glass melt is sufficiently mobile.

Another source of trouble may be corrosion of the tank or pot walls whereby alumina is introduced as a silicate into the melt, thereby changing its viscosity locally; under these conditions cords may be expected in the glass in addition to surface-markings. The process of assimilation of clay material dissolved from the walls of the container is necessarily slow and the chances are favorable that strings, threads, and ribbons of the dissolved material are carried by convection or other currents into the body of the molten glass mass, and may persist as streaks of slightly different composition for long periods of time. Striae mark the stream lines or paths taken by some of these currents within the pool of molten glass. In each case it is desirable to ascertain the cause

of the local inhomogeneity in composition and to trace it back to its source. The following relations are significant in this connection. Observation has proved that the composition of the surface, to a depth of half a millimeter or more, of a pool of molten glass is slightly different from that of the main body of the melt. This is true even in an optical glass melt which is stirred vigorously for many hours. This surface film is higher in silica and lower in alkalies than the underlying glass; its formation is due to selective volatilization, especially of the alkalies, from the liquid glass. Its refractive index is lower than that of the subjacent glass; it is also generally more viscous because of its higher silica content and if carried down into the body of the melt gives rise to striae which, if heavy, are objectionable. In case alumina is introduced from the walls of the container, streaks of glass richer in alumina are to be expected and these, in ordinary glasses, may have a higher or a lower refractive index than the adjacent glass. If the refractive index of a cord is found to be higher than that of the glass surrounding it, the source of trouble may be corrosion of the container walls (pot solution) or an original difference in composition not entirely eliminated by diffusion within the pool of molten glass.

In a large pool or pot of molten glass the conditions are such that homogeneity throughout the mass is not and probably can not be attained. This means that, because of currents and differences of viscosity, some cords and striae are ever present within the metal and in process of further attenuation and assimilation. It is the task of the glass maker to keep these striae within bounds so that in the finished article they are fine and scarcely noticeable except on close inspection. The more definite facts he can obtain regarding cords and surface markings in any given case the better is he able to infer the real source of trouble.

The reason why cords and striae are visible in glass is because their index of refraction is different from that of the surrounding glass. If it were possible to ascertain the refractive index of a given cord or even its refringence relative to that of the glass in which it is embedded, a series of simple experiments with any given glass composition would enable the glass maker to determine the effects which changes in the composition of the glass produce on

the refringence relations. Having thus ascertained, for example, the changes produced by the addition of clay (pot-solution) and compared its effect with that produced by an excess of silica or a decrease in alkalies, he is able to state with some assurance in a given case whether pot-solution or volatilization is the cause of the cords.

The methods for distinguishing surface markings from cords are fortunately easy of application and do not require elaborate apparatus; furthermore the refringence of a cord relative to that of the surrounding glass can be readily ascertained. These methods will now be described briefly.

The effect of irregularities in the surface of glass on rays of light is to deflect them from their straight course. The more pronounced the markings, the greater the degree of deflection and the more readily are the markings seen. Their effect on rays of light is similar to that exerted by a hand lens or a burning glass, namely, to refract and diffract the light. The amount of deflection produced by a given lens or surface corrugation depends on the difference in refringence between the glass and its surrounding medium. It is possible to choose a liquid which for a given color of light has exactly the same refractivity as the glass; in this case the rays of light pass through the glass surface into the liquid without any perceptible deviation; the surface markings disappear altogether and can not be seen even under the most favorable conditions of observation. Cords and striae, on the other hand, are completely surrounded by glass and the liquid does not come into contact with them; under these conditions they do not disappear when the glass is immersed in a liquid of the same refractive index but become more conspicuous because all surface irregularities are virtually suppressed and these tend ordinarily to obscure or veil striae.

The refractive index of ordinary crown glasses for yellow light ranges between 1.515 and 1.525, and for these a satisfactory immersion liquid of about the same refractive index is mono chlorbenzene.[1] To determine whether the cord or striae-like mark-

[1] Obtainable from any dealer in chemical supplies. In a recent list from the Eastman Kodak Company the price for 5 kilograms of monochlorbenzene is stated to be $3.

ings exhibited by a piece of glassware are actually cords or surface markings the article is viewed first in air and then while immersed in a tank of monochlorbenzene. A suitable tank can be made by bending a flat piece of heavy metal (iron, brass, or copper) into a flat-bottomed U-shape; this forms the bottom and two ends of the tanks; the two sides are of plate glass cemented to the metal with a mixture either of Le Page's glue and plaster of paris or of lime and zinc oxides in sodium silicate (water glass). A square fish aquarium serves the purpose well, provided its sides are of plate glass. For these experiments a distant source of light (electric lamp bulb ten or more feet distant) is used (figure 1).

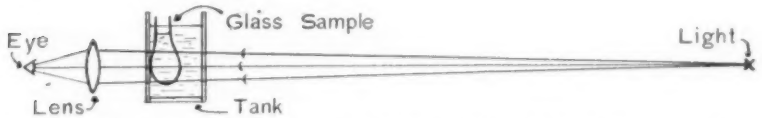


FIG. 1.—Optical arrangement suitable for distinguishing between surface-markings and cords. The glass sample is immersed in a liquid having the same refractive index and contained in a tank with parallel glass sides. The immersed sample may be viewed against a distant light with or without the aid of a hand lens.

Surface markings on a piece of glass examined under these conditions of immersion disappear altogether, whereas striae and cords stand out more clearly than ever. It may be noted that in every case it is necessary to have all surfaces of the article under examination in contact with the liquid in order to avoid total reflection and other disturbing phenomena. This means that lamp bulbs, tumblers, and other hollow articles should be filled with the liquid as well as immersed in it.

A simple test to ascertain if the liquid and the immersed piece of glass have the same refringence is to sight through the immersion tank toward the distant light and to note that the light does not shift its position when the immersed piece of glass is placed in the line of sight. If the light does shift, the refringence of the liquid is either too high or too low. Let us suppose the piece of glass is wedge shaped. Move it so that the thin edge crosses the line of sight first; then if the light is seen to shift *toward* the glass block, the liquid has a lower refractive index. Thus if the

block with its sharp edge to the left, is moved across the line of sight from right to left and the source of light is thereby deflected toward the right, the refractive index of the liquid is too low, and vice versa. When the refractive index of the liquid and glass are the same for yellow light, red and blue color fringes appear on opposite sides of the glass block. The refractive index of the immersion liquid can be lowered by the addition of benzol or some still lower refracting liquid; it can be raised by adding monochlornaphthalene[1] or carbon bisulfide or other strongly refracting liquid.

The immersion test is extremely simple and enables the operator to determine definitely at a glance whether the source of trouble is surface markings or cords. It is a fact of observation that in blown or pressed ware the surface markings are confined chiefly to the exterior surfaces and appear rarely on the inner surfaces.

With the aid of a pocket hand lens or low-power magnifying glass (watch-maker's glass) it is possible at the same time to determine the refringence of a cord relative to that of the adjacent glass. To do this, sight toward the distant light through the magnifying glass and in the direction of the glass article immersed in the tank (figure 1). Move the eye and lens toward or away from the piece of glass until the cords are brought to sharp focus and the fine details can be readily seen. Now draw the eye and lens a short distance back from the position of sharp focus and observe the change in illumination over the cord or striae. In case the cord has a higher refractive index than the glass, the rays of light are convergent and the center of the cord in the new position appears brighter than the adjacent field. The reverse is true for a cord of lower refractive index; also for a cord of higher refractive index when the eye and lens are moved from the position of sharp focus nearer to the cord. In these cases the center of the cord appears darker than the adjacent field.

Under these conditions of observation, diffraction phenomena give rise to series of narrow alternate light and dark bands which at first may be disturbing to the observer; but after a few trials their presence is recognized as inevitable and they do not actually

[1] Made by the Condensite Company of America, Bloomfield, N. J., under the trademark "halowax oil."

interfere seriously with the results. They can be largely eliminated if a different mode of illumination be used, namely, a ground-glass plate, a foot square, not too far distant (several feet), and illuminated from behind by an electric lamp bulb; directly in front of the plate a perforated screen or lattice work is placed. The bars in a distant window may serve the purpose equally well. Under these conditions of oblique or half-shadow illumination, the cords exhibit a one-sided illumination and appear to stand out in relief. In this method a hand lens is not required, but may be used to render details more easily seen. From the relation of the shadow-side of the cord to that of the direction of the incident light the relative refringence of the cord can be readily deduced. For example, let the line of sight be toward the sky or horizon as seen through a distant window. Bring the sample of glass into the line of sight and look at it instead of at the distant window. Note that now the sides of the window are no longer sharp; but there is a gradual transition from light near the center of the window to dark beyond the sides. If a cord in the glass sample falls within the half-shadow on the left of the window and the side of the cord facing the shadow (left side) is brighter than the opposite (right) side, the refringence of the cord is higher than that of the surrounding glass. Because of the variety of shapes of cords, several cords should be tested before a definite conclusion is reached. If surface-markings are present, the sample should be tested while immersed in the proper liquid.

GEOPHYSICAL LABORATORY
CARNEGIE INSTITUTION OF WASHINGTON
MARCH, 1921

ZIRCONIA CEMENTS[1]

By Mark Sheppard

ABSTRACT

The effect of calcined zirconia on zirconia cement. Seven refractory cements were made having compositions of zirconia 90 per cent and plastic clay 10 per cent. (1) **The shrinkage** was found to be excessive in a cement containing raw zirconia and clay. The addition of 50 per cent or more of calcined zirconia practically eliminated this shrinkage and the cracking which accompanies it. (2) **Strength.** Draw trials showed that the cement became strong at 1200°C and that it was very strong when burned at 1700°C. (3) Load tests on piers at 1500°C showed that joints of these cements did not fail in any manner at this temperature. (4) An industrial test of zirconia cement used as a wash for bungs in a malleable iron furnace showed that the life of a bung was increased about 25 per cent by the use of a zirconia wash.

Introduction

Zirconium and its salts have been used in several industries, although not in large amounts. Pure fused zirconia has a linear coefficient of expansion of 8.4×10^{-7} and a fusion point of about 2600°C.[2] The thermal conductivity of zirconia brick is approximately half that of fire-clay brick.[3] It is comparatively inactive in the presence of either acidic or basic materials at high temperatures. These properties have lead many investigators to experiment with zirconia for refractory purposes. Much of this work has been in the production of laboratory ware from zirconia containing at least 99 per cent of ZrO_2. Bricks and cements have also been made from crude zirconia containing from 75 to 80 per cent of ZrO_2.

The great difficulties in the use of zirconia as a refractory have been the excessive shrinkage, the lack of a suitable bonding material and the high cost. The first two apply more particularly to the use of zirconia in electric furnaces at the most extreme temperatures. The cost is of more importance in the case of furnaces which operate at more moderate temperatures.

[1] Received, April 15, 1921.

[2] Average of the determinations of several investigators.

[3] H. C. Meyer, *Chem. Met. Eng.*, **13,** 263 (1915).

The Brazilian deposits of zirconium oxide are so large that zirconia has ceased to be in reality a rare earth—in fact, the cost is low enough to make zirconia an important refractory material. The deposits of zirconium silicate are also large, although very little research work has been done in this field.

The present uses of zirconia as a refractory are in the making of bricks and refractory cements for metallurgical furnaces, and in crucibles and laboratory ware. Zirconia has also been used as an opacifier in enamels, as a resistance body in the Nernst lamp as an incandescent coating for gas mantles, and as a white pigment for paint. Zirconium has been used in alloys with several other metals, the most important of which is ferro-zirconium.

Experimental

A series of refractory cements was made and tested, both in the laboratory and in actual practice, for use either in laying refractory brick or as a protective coating.

Two grades of zirconia were available for this work. Their characteristics are as follows:–

	Chemical Analysis	
	Crude zirconia	Refined zirconia
ZrO_2	74.04	94.57
SiO_2	17.62	0.20
Fe_2O_3	3.84	2.29
Al_2O_3	3.58	2.20
TiO_2	0.85	0.83
Total	99.93	100.09

The crude zirconia is of the grade commonly imported. Its color is gray or brown, depending on the state of oxidation of the iron. Its specific gravity is 4.83 and its hardness is 5.5 to 6.0. It has considerable burning shrinkage, which increases as the temperature is raised, making it necessary to burn refractories of this material to a temperature as high as that at which they are to be used. The shrinkage[1] at 1400°C. is 9 per cent. With the addition of 7 per cent clay, the shrinkage increases to 12 per cent. To lessen the shrinkage for use in cement, the crude zirconia was calcined at 1450°C. This calcination increased the specific gravity from 4.83 to 5.12.

[1] H. C. Meyer, *loc. cit.*

In the refined zirconia all the silica, together with a part of the iron and alumina, has been removed. The specific gravity is 5.18. It has no shrinkage after it has been burned at 1550°C. and it is much harder than the crude ore.

Since zirconia posesses no plasticity, 10 per cent of ball clay was added to each batch to give better working qualities and to make the cement adhere more firmly.

The analysis of the clay used was:

SiO_2	48.94
Al_2O_3	36.69
Fe_2O_3	?
CaO	0.47
MgO	0.71
Alkalies	11.28
Ignition loss	2.14
Total	100.58

The following series of cements was made up from crude zirconia and clay for the purpose of determining the amount of calcined material needed to prevent excessive shrinkage and the cracking which accompanies it.

1.	Raw crude zirconia	90
	Clay	10
2.	Raw crude zirconia	70
	Calcined crude zirconia	20
	Clay	10
3.	Raw crude zirconia	40
	Calcined crude zirconia	50
	Clay	10
4.	Raw crude zirconia	20
	Calcined zirconia	70
	Clay	10

It was desirable to keep the clay content as low as possible so that the refractoriness of the cement would not be lowered. Ten per cent of clay was found to give a cement of satisfactory strength and consequently it was used throughout.

Three members containing refined zirconia with crude zirconia were added to the series. The compositions were:

5.	Refined zirconia	45
	Raw crude zirconia	45
	Clay	10
6.	Refined zirconia	60
	Raw crude zirconia	30
	Clay	10
7.	Refined zirconia	75
	Raw crude zirconia	15
	Clay	10

These members were added both for the study of elimination of the shrinkage and also with the idea of getting a more refractory cement. The screen analysis of the zirconia was, percent:

Through 20-mesh	100.0
Retained on 40-mesh	40.0
Retained on 60-mesh	18.4
Retained on 80-mesh	8.8
Retained on 100-mesh	13.6
Retained on 150-mesh	2.2
Retained on 200-mesh	6.8
Through 200-mesh	9.7

The clay was screened through 40-mesh.

The cements were mixed with 18 per cent of water to a rather wet mortar, and a coating about 3/16 inch thick was spread on one face of a fire brick. The test specimens were thoroughly dried, heated to 1400°C., and held at that temperature for five hours. Cracks were noticeable in cements No. 1 and No. 2 after being burned. The cracks in No. 1 were apparent after drying, but those in No. 2 were produced in burning. No. 3 cracked slightly but not seriously. In No. 4 the cracking was negligible. No. 5 cracked very slightly and appeared to be about equal to No. 4. Nos. 6 and 7 did not crack at all.

The color was determined entirely by the proportions of crude and refined zirconia. The crude ore imparted to the cement a dark brown color in the presence of 10 per cent of clay, while the color of the refined ore was considerably lighter. Cements No. 1 and No. 2 did not adhere very well because of their high shrinkage, but the remainder of the series adhered excellently.

A pier was made of silica splits with cements, Nos. 3, 4, 5, and 6 used in the joints. The joints were made 1/4 inch in thickness. This pier was tested under a total load of 400 pounds (25 pounds per square inch). The furnace was raised to 1500°C in six hours and held at this temperature for one and one-half hours. At the completion of the test no change of volume, compression, or other sign of failure was noted in the cement.

Further tests showed that these cements possessed rather low dry strengths, but after heating to 1200° C., they were sufficiently strong to withstand furnace conditions. Since a material of this kind would not be applied for service at temperatures below 1300° or 1400°C, a satisfactory bond is assured. Draw trials made at 1700°C had a cold strength similar to that of magnesite brick.

For use up to 1700°C the refined zirconia additions did not improve the cement noticeably. At considerably higher temperatures the refined zirconia cements would undoubtedly be better than those containing crude zirconia.

Industrial Test

A test on zirconia cement No. 5 as a wash for bungs was carried out in a malleable iron melting furnace. It was found that bungs which had their bricks dipped in a thick paste of zirconia cement lasted about 25 per cent longer than bungs washed with the fire clay customarily employed. The following is an excerpt from the report of this test:[1]

"The first test with three bungs was started on November 8, 1920, in our No. 2 melting furnace. The first bung (A) was washed with our own fire clay; the second bung (B) was washed with your zirconia wash; the third bung (C) had its bricks dipped in a thick paste of the zirconia wash. Bungs A and B were liberally washed three times, the bricks being allowed to dry almost completely between washings.

[1] Private communication of C. W. Rodman, to whom the writer wishes to acknowledge his indebtedness for coöperation in supervising the practical test in the malleable iron foundry.

"These bungs were placed next to each other, A being the seventh from the front bridge wall, B the sixth, and C the fifth. The bungs were in the arch which deflects the flame on the bath and in the opinion of the writer, this is the severest service in the furnace. Bung A lasted twenty heats, bung B twenty-two heats, and bung C thirty-one heats. A and B might have lasted one or two heats longer, but were replaced by new ones as a falling bung causes trouble. Bung C, however, after twenty-two heats was removed and placed directly over the front bridge wall, where it was subjected to very severe treatment. We allowed this bung to remain until it fell in, desiring to see just how long it would last.

"Another test of five bungs was started December 1st. Three bungs A, B, and C were dry, no wash being used; D and E had their bricks dipped in zirconia wash. These bungs were placed in the middle of the furnace and in such a position that they did not have to be moved. These bungs were level. A and C lasted twenty-one and twenty-two heats, respectively, E twenty-nine heats and B and D are still in use. The positions of these bungs were as follows: B was in the middle of the furnace; on one side of B, bung D was placed, on the other side, bung E; directly next to D was placed A, and next to E was placed C. From the position we can see the extreme bungs A and C would be subjected to the greatest abrasion during charging, and it was these bungs which failed first. The other three bungs were somewhat protected by these end bungs."

In this test it is noticeable that the bungs which had their bricks dipped in the zirconia cement gave considerably longer service than those in which the cement was merely washed onto the completed bung. This emphasizes an important point in the use of protective washes, *viz.*, that the wash should be applied in a thick coat, preferably about $^3/_8$ of an inch thick, and it should extend back into the joints. A protective wash which is very thin and which has a high thermal conductivity does not protect the brick from vitrification. The latter, as soon as they become dense, show a much greater tendency toward spalling[1] with a consequent loss of the coating of cement.

[1] Howe and Ferguson, THIS JOURNAL, **4**, 32 (1921).

Summary

1. Raw zirconia alone cannot be satisfactorily used as a cement because of its high shrinkage.

2. The addition of 50 per cent or more of calcined zirconia produces a strong cement which does not crack in drying or in burning, and which becomes mechanically strong at 1200°C.

3. The addition of 10 per cent of clay does not seriously reduce the refractoriness.

4. The use of zirconia cement as a wash on malleable bungs lengthened their life about 25 per cent.

THE MELLON INSTITUTE OF INDUSTRIAL RESEARCH OF THE
UNIVERSITY OF PITTSBURGH
PITTSBURGH, PENNSYLVANIA

THE APPLICATION OF PRODUCER GAS TO PERIODIC MUFFLE KILNS[1]

By F. B. Ortman

ABSTRACT

Specific Installation.—Describes installation of Underwood System to six terra cotta kilns at plant Northwestern Terra Cotta Company.

Conclusions from operating data.—(1) Raw producer gas can be successfully applied to periodic muffle kilns. (2) There is little or no direct fuel economy over direct firing. (3) There is no labor economy unless the installation be large enough to justify mechanical coal and ash handling devices. (4) When interest on investment, depreciation and all other pertinent factors are taken into account, it is not likely that any great economy would be affected on periodic kilns over direct fire methods.

Advantages.—They are: (*a*) Somewhat better control of combustion gases and kiln temperatures. (*b*) Decided saving in kiln repair costs. (*c*) Cleaner and more orderly kiln yard. (*d*) Abatement of smoke nuisance, particularly important in large cities.

Introduction

The use of raw producer gas as a fuel for the burning of periodic muffle kilns is, we believe, a rather uncommon practice. In fact, the only installation of this kind of which the writer has any knowledge, is that put in at the plant of the Northwestern Terra Cotta Company, Chicago, early in 1918. This installation was operated continuously for a period of six or eight months, but has not been operated since that time. It was not discontinued because of its having proven a failure but because of other considerations quite aside from its performance and of no particular interest in this connection.

In the hope that the experience with this installation may be of interest to others the following data, taken from various reports and notes made at the time are presented here.

It should be emphasized at the outset, that the experience with this installation was confined entirely to muffle kilns burning architectural terra cotta, which presents an entirely different problem from an open kiln burning brick, etc.

[1] Received April 2, 1921.

Installation

The installation consisted of two rectangular up-draft brick producers, 9′ x 15′ inside and fired from the top through three of the usual bell-feed hoppers. They were equipped with a water-sealed ash pit, the air and the steam being admitted by means of a steam injector to a tuyere running longitudinally along either side of the producer under the fuel bed.

The gas from each producer emptied into a main underground duct from which it was taken off by underground distributing flues to each of two 18 ft. diameter kilns and three 19 ft. diameter kilns. Each kiln had nine fire boxes equipped with gas burners supplied by The Manufacturer Equipment Company. The kilns were of the usual round, up and down draft, muffle type and were all practically identical in design. The 18-ft. kilns would have a capacity of about thirty-two burned tons and the 19-ft. kilns about forty burned tons.

The air for combustion was supplied at a pressure of about 8 oz. by a small blower fan, and was conducted around the kilns overhead in a 12″ galvanized duct. It was not preheated, being applied at the burners at outside atmospheric temperatures.

Operation

The successful adaptation of producer gas to kilns of the type in question involved the solution of two problems, *viz.*, The Producer Problem and the Kiln Problem.

Producer Problem.—The conditions necessary to maintain, in order to produce a good quality of gas, are perhaps much the same as in any other type of producer installation. The requirements, however, are somewhat different from those of a continuous kiln or other similiar installations, in at least two respects.

First: The gas must constantly be maintained at high quality and burned with as low an excess of air as possible, in order that the volume of combustion gases may be kept at a minimum. Otherwise, the comparatively complicated flue spaces which exist in kilns of this type will become overloaded, and choked, resulting in excessive heat in the combustion chamber and an uneven burn. In the burning of brick or other material in open kilns, it is reported to be of distinct benefit, especially during the water

smoking period, to burn the gas with large volumes of air, since the excess air thus introduced performs the very necessary function of assisting in the rapid removal of the water. In the muffle kiln, however, this excess air performs no such function, the air for water smoking being supplied from other sources quite independent of the combustion gases.

Second: The gas must be fed to the burners primarily by pressure, rather than by suction, as in the case of continuous kilns, for example. This introduces another factor influencing the possible adjustment of the steam and air at the producer, quite apart from the adjustment which might be necessary for producing the best quality of gas. This is particularly in evidence when a kiln is first lighted and before a good stack draft is established.

In order to meet these requirements, therefore, it is necessary that the producer plant be kept at the highest possible state of efficiency. Our experience with the above installation indicated that the following were the essential factors for obtaining this result.

First: Ample capacity, in more than one unit. This is obviously necessary in order that the supply and quality of gas may be maintained under varying loads, and during breaking down and cleaning of fuel beds.

Second: The selection and use of the best possible coal commercially available. Such a coal should be as nearly uniform in size as practical, and not too large. It should also carry a low sulphur and ash content. Probably a washed nut would be the ideal coal, although in some markets, natural coals might be available which would be more economical.

Third: The careful regulation and standardization of operating conditions, such as steam and air supply, amount of coal and frequency of firings, frequency of pokings of fuel bed, breaking down, cleaning, etc. These conditions vary greatly with different coals and can only be adjusted by actual experience on part of the operators. It is important, therefore, that after a suitable coal has been found, every effort be made to insure a steady supply of same, as every change of coal results in at least a temporary drop in the efficiency of the producer.

Kiln Problem.—Being assured of a steady and ample supply of a good quality of producer gas at the burners, it then becomes necessary to burn the same economically and with satisfactory results in the kiln. The first difficulty one would expect to encounter in this respect, *viz.*, the use of cold air for combustion, was satisfactorily solved by the Underwood Burner. This burner, while simple in design, proved efficient, and permitted control of the excess air and flame length somewhat more accurately than is possible by the direct fire method, always assuming, however, that the producer was delivering a good and uniform quality of gas.

Another point observed is the effect on kiln linings, flues, etc. While the operation was not continued a sufficient length of time to supply definite data on this point, it was clearly apparent that the uniformity of fire-box temperatures maintained with the gas firing, greatly reduced the necessary kiln repairs.

Comparative Economy

The economy of this type of installation as compared with direct fired kilns, is of course a very vital point. Careful measurements of fuel consumed, over a sufficiently long period of continuous operation to be reliable, showed us that the actual coal fed into the hoppers of the producer per kiln or per ton of terra cotta burned, was slightly less than the same kilns had been requiring under direct firing. If however, the producers were charged (as they should be) with the coal required to furnish steam and power necessary for operation, then the relative economy was slightly in favor of direct firing.

On the installation in question there was no saving in labor cost. Possibly a larger installation which would justify mechanical coal and ash handling devices would show some saving in this respect.

Quality of Ware Produced

There was no appreciable difference observed in the quality of ware produced, it being equal in every respect to that produced under direct firing.

GLENDALE, CALIF.

CONTINUOUS TUNNEL KILNS AT THE PLANT OF MOUNT CLEMENS POTTERY COMPANY[1,2]

By C. B. Harrop

ABSTRACT

These two direct-fired kilns (bisque and glost) are placed end to end in a specially constructed kiln building 825 feet long. Both kilns are fired with soft coal, hand stoked. Three motors are required, aggregating 8¼ horsepower on each kiln. Hydraulic car pushers are employed. A pressure of 8100 lbs. is required to move the 44 cars thru the bisque kiln. The bisque kiln cars hold 278 dozen ware each and at a 55-minute car schedule, deliver over 7200 dozen ware per 24 hours at a fuel saving of more than 85% over the former periodic kiln operating at this plant. This bisque capacity is equivalent to that of thirteen 16½ ft. diameter periodic kilns which would cost more to build than the bisque tunnel kiln.

The two Continuous Tunnel Kilns built by the Mount Clemens Pottery Company, Mount Clemens, Mich., for firing semi-porcelain tableware and just recently put into operation, are probably unique for several reasons.

First, the two kilns are placed end to end, on the same center line, necessitating probably the longest building in the country used exclusively for housing kilns.

Second, the kiln installation is one of the very few firing white ware, in which coal is being successfully used as fuel.

Third, the kilns are open- or direct-fired and the furnaces are hand stoked without resulting in loss from fluctuating temperatures, reducing conditions or ash deposit upon the ware.

The bisque kiln is 323 ft. 6 in. long and operates at cone 10. The glost kiln is 273 ft. 6 in. long and operates at cone 6.

The building which houses the kilns is 825 ft. long by 70 ft. wide; is of modern daylight factory construction with brick walls, steel sash windows, steel roof trusses and a wide center monitor the full length of the building. Space is provided for a duplicate pair of kilns and also for additional drawing and loading tracks.

[1] Received March 10, 1921. Read at the Columbus meeting, Feb. 1921.

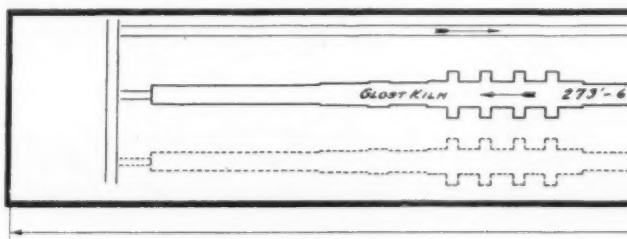
[2] Mount Clemens, Mich.

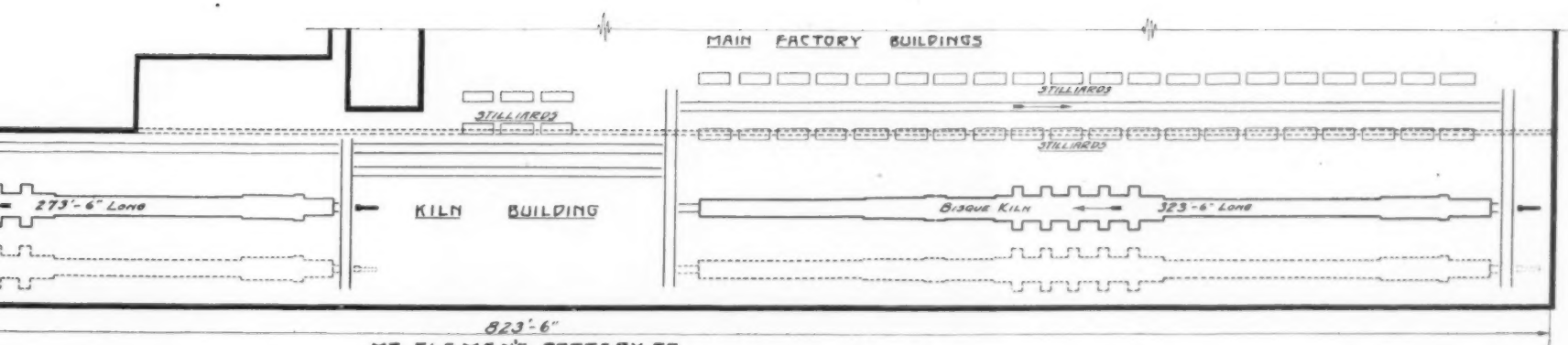
Figure 1 shows the general layout of the present kilns and also the duplicate installation.

Figure 2 is a view of the charging end of the bisque kiln, showing the rolling steel charging door, a car of ware ready to enter and the hydraulic ram, which will be described later.

Figure 3 shows the battery of five furnaces on one side of the bisque kiln, only three of which are necessary to maintain the kiln temperature. The grates are an "Underwood" pattern, specially designed for these kilns and consist of a cast iron grate plate with a hollow box below connecting into two long tuyeres located on top of the plate and running transversely with respect to the furnace. The inside of the furnace proper measures 24 in. by 27 in. and a fuel bed about 15 in. thick is maintained. The side walls, front wall and bridge wall are air-cooled to prevent clinker building onto the masonry. The air used for this purpose serves as primary air for combustion and enters the fuel bed with steam thru the tuyeres. Manually operated drag chains remove the ashes from the grate plate. Just inside of the charging door is an inclined coking table. A small scoop of coal, about 13 lbs., is charged on to this coking table at 20 minute intervals,—the coke being pushed off the coking table and spread over the fuel bed before fresh coal is added. Three secondary air inlets are provided on each side of the charging door, being supplied with air which is preheated by passing over the crown of the cooling end of the kiln and then over the furnace arch. The furnace throat is greatly enlarged as it enters the tunnel proper, the purpose of which is to reduce the velocity of the furnace gases as they come in contact with the kiln setting.

As these kilns are direct-fired, they are essentially horizontal draft kilns. A characteristic of this type of tunnel kiln (as also with the muffle type, in fact) is that the top part of the setting of ware is subjected to greater heat than the lower portions, due to the tendency for the heated gases to rise in the tunnel and travel in the upper levels. The means employed to compensate for this natural tendency is clearly shown in figure 4, which is a typical





MT. CLEMEN'S POTTERY CO.
MT. CLEMENS, MICH.

FIG. 1.

FIG. 2.

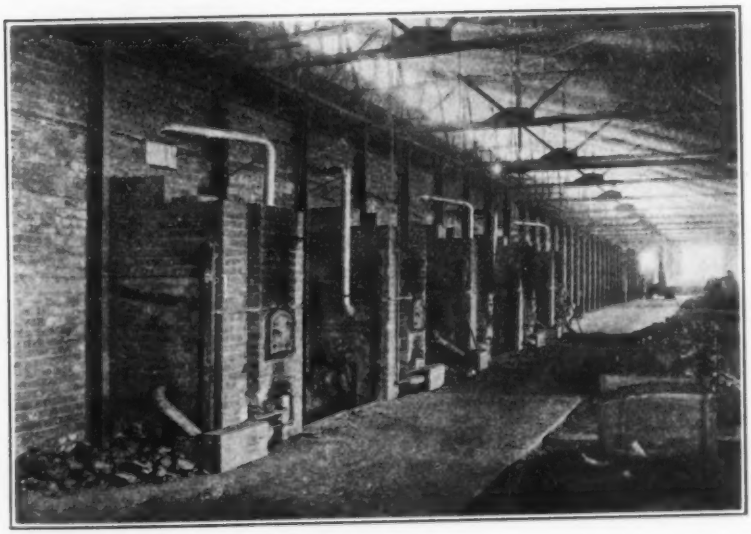


FIG. 3.

cross section through the high temperature zone. Gases will tend to travel through large spaces rather than small ones. Or, stated differently, gases will tend to avoid spaces with great frictional resistance and will seek paths of lesser resistance. Therefore, in the construction shown, even tho there is a tendency for the furnace gases to rise in the tunnel, they will not do so to any undesirable extent, because the free area in the upper part of the tunnel through which they can travel horizontally is so small and presents so

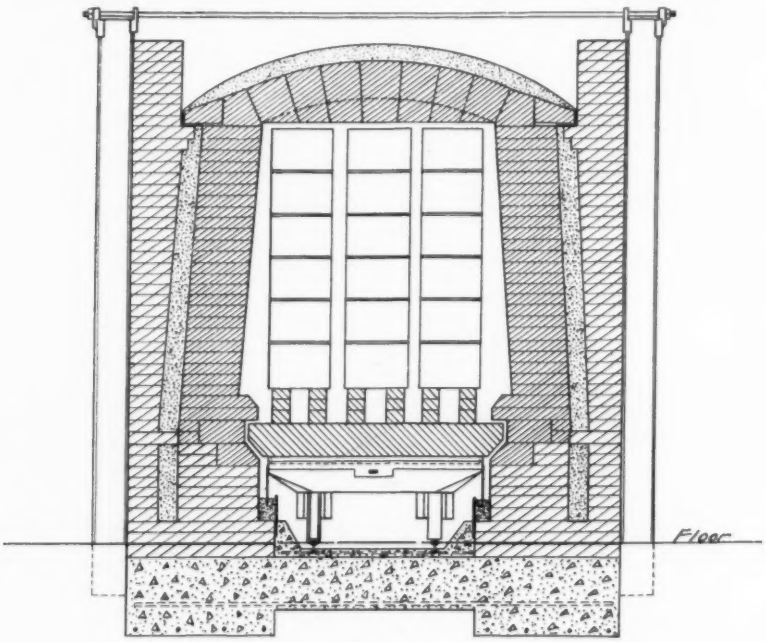


FIG. 4.

much friction that they will naturally seek the larger clearances at the lower levels, including the spaces between the lowest setting and the car platforms. As can be seen from the sectional view, this is accomplished by depending baffles under the kiln crown (or by the use of baffle blocks or stop blocks, superimposed on the car setting), by battering the side walls of the tunnel and by stilting the ware up from the solid car platform, which really never gets as hot as the side walls or crown of the kiln.

This cross sectional view also shows the heat insulation, which is heaviest at the high temperature zone and less towards the ends of the kiln.

The car platform is a single gray iron casting. The wheels are larger than those used in other tunnel kilns, which results in an easier movement of the car. The wheels on one side are double-flanged and those on the other flat-faced. Each wheel is mounted on a separate axle and is equipped with a cage roller bearing. The superstructure of the car consists of $2^1/_2$ inches of heat insulating cement and a single course of refractory blocks 9 inches thick. The car is unusually light considering its size,—the finished top measuring 4 ft. $11^1/_2$ in. wide by 7 ft. $1^1/_2$ in. long.

The mechanical equipment of each kiln consists of a blower driven by a 3 H.P. motor, a draft fan driven by a 5 H.P. motor and a hydraulic ram. The ram was specially designed for these kilns. It is entirely self-contained carrying the oil for operating in a reservoir in its base. The piston returns automatically at the end of its stroke. The triplex oil pump is operated by a variable speed $^1/_4$ H.P. motor.

So far as is known there are no published data as to what force is necessary to move the cars thru a tunnel kiln. It was, therefore, decided to accurately determine this in connection with these two kilns. A pressure gage was connected with the cylinders of both rams and showed that the bisque kiln, holding 44 cars at one time, required a force of 8100 lbs. to propel the train of loaded cars. The force required to propel the 37 loaded cars in the glost kiln is 4860 lbs.

The pyrometric equipment of these kilns consists of one recording and one indicating galvanometer, 15 thermocouples in the bisque kiln and 12 thermocouples in the glost kiln,—noble metal couples being used in the high temperature zones and base metal couples in the cooler parts. Compensating leads and insulated cold junction boxes are provided for all couples.

Several different coals have been tried in these kilns and "Elkhorn" Kentucky gas coal has proven most satisfactory. On February 9th and 10th, at which time the cars were being charged at $1^1/_4$-hour intervals, a very careful fuel test was conducted on the bisque kiln and showed a 24-hour fuel consumption of 6710 lbs.

From this test, 1.22 lbs. of coal are required per dozen of ware. The periodic kiln records at this plant show that the bisque kilns hold 4100 dozen and require 16 tons of coal, or 7.8 lbs. of coal per dozen ware. Comparing these figures, the bisque tunnel kiln requires but 15.6 per cent of the fuel used in the periodic kilns, or there is a fuel saving of 84.4 per cent.

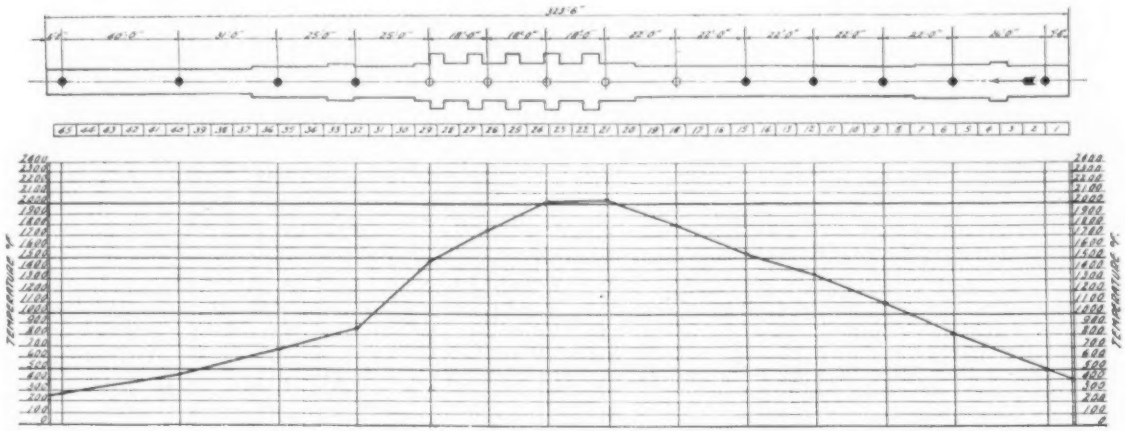
The bisque kiln was planned to operate on a 1-hour car schedule and in order to test the capacity, the kiln was operated for over two days at a car schedule of 55 minutes, or 26 cars per 24 hours. Under this increased production (over 7200 dozen ware per 24 hours), the additional amount of fuel required is practically negligible. With a fuel consumption of 7000 lbs. under these conditions, the fuel saving was 87.6 per cent.

A fuel test was conducted on the glost kiln at the same time, under a 1-hour car schedule,—each car carrying 131 dozen ware. 5670 lbs. of coal were used in 24 hours, or 1.8 lbs. per dozen ware. The periodic glost kilns hold 2900 dozen ware and require 14 tons of coal. This shows a fuel saving in the glost kiln of 81.3 per cent. This kiln was operated for a while on a 37 minute car schedule and at this rate of operation would undoubtedly show a fuel saving of over 90 per cent. The maximum practical rate of car movement has not yet been determined for either kiln, but it is safe to say that the rates tried thus far can be easily exceeded, especially in the glost kiln and without any detriment to the quality of the ware. The foundation's for these kilns were begun the second week in June, 1920, each foundation requiring about one week to pour. Due to delayed delivery of brick, the mason work was not begun until July 26th. The bisque kiln was lighted November 24th and the glost kiln January 12th, 1921.

On the basis of capacities already proven in these kilns, and comparing with their past periodic kiln operation, the bisque tunnel kiln has a capacity equal to 13 periodic kilns and the glost tunnel kiln has a capacity of 11 periodic kilns, or, the two tunnel kilns have already shown a capacity equal to 24 periodic kilns, which at $5000 each would represent a greater investment than the two tunnel kilns complete. As stated before, the tunnel kilns have not been pushed to their limit, so that the above comparison is conservative.

AT MOUNT CLEMENS POTTERY CO.

MOUNT CLEMENS POTTERY CO.
MOUNT CLEMENS, MICH.



BISQUE

TEMPERATURE RECORD

HARROP CONTINUOUS TUNNEL KILN

DATE Feb 10-1921 HOUR 2 PM. CAR SCHEDULE 1 hr. 15 min. CONE 10 TAKEN BY W. E. Cramer

FIG. 5.

In regard to kiln losses, no accurate determination of this has been made. However, in the opinion of the superintendent the loss in the bisque tunnel is much lower than in the periodic kilns. This is to be expected, as there is practically no loss from flashed ware or from over-firing or under-firing, as the temperature and atmospheric conditions are practically constant.

Figure 5 is a temperature record, showing the temperature gradient throughout the length of the bisque kiln and is self-explanatory, although it might be stated that the temperatures noted are taken about 3 inches under the crown of the kiln and do not indicate the temperatures of the ware at the several points.

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* The abbreviation (*C. A.*) at the end of an abstract indicates that the abstract was secured from the Editor of *Chemical Abstracts* by coöperative agreement.

General and Miscellaneous

1. Possibilities of ceramic industries in Nova Scotia. JOSEPH KEELE, Ottawa Dept. of Mines. *Canad. Chem. Met.*, **5,** 20 (1921). Ed.

2. Distribution of scientific information in the United States. ROBERT B. SOSMAN. *J. Washington Acad. Sci.*, **11,** No. 4, Feb., 1921.—The production of new information in the United States is much better managed than its distribution. It is distributed through five main channels: (1) by personal communication or through the "informational middleman;" (2) by public lectures; (3) by the museum and public exhibition; (4) by the printed page—books, scientific and technical periodicals, bulletins, general periodicals, newspapers, and separates; (5) by the cinematograph. Ineffective distribution results from (1) disinclination to use new knowledge, a cause not discussed in this paper; (2) the inaccessibility of scientific information, arising from (*a*) the bulky form in which it comes from the producer, (*b*) its heterogeneous character, and (*c*) the arithmetical or psychological limitations peculiar to each method of distribution. The bearings of these various factors on existing methods of distribution, both to producers of information and to the general public, are touched upon, and desirable or probable future developments in each are briefly discussed. Ed.

3. Work of the ceramic station of the Bureau of Mines at Columbus, Ohio, in behalf of the ceramic industry. *Repts. Invest. Bur. Mines*, **1921,** No. 2212, 5 p. (*C. A.*)

4. Overhead expenses—How to distribute them in good and bad times. ANON. *Special Rep.*, U. S. Chamber of Commerce, Fabricated Production Department.—The subject is discussed under the heads: elements of a mfg. enterprise; the activities involved; operations cease, but do expenses? the consumer pays? a normal year—the business standard; operation under a normal year basis; necessary cost system adjustments; some misunderstandings clarified; found feasible in practice; conclusion. This and other pamphlets on the same subject will be sent on request addressed to Fabricated Prod , Dept. U. S. Chamber of Comm., Mills Bldg., Washington, D. C. Ed.

5. Lime as a source of trouble in clay. DR. ZIMMERMANN. *Tonind. Ztg.*, **44,** 993 (1920).—When lime is present in clay its tendency to slake may be overcome by soaking the ware in firing sufficient to cause the lime to combine with the clay, thus dead-burning the lime. H. G. SCHURECHT

6. Porous brick and ceramic products. G. B. *Rev. Mat. Constr. Trav. Pub.*, **136,** 11B (1921).—Organic materials such as cut grass, oats, or other cereals, tan bark, coke dust, wood shavings, saw-dust and peat may be substituted for coal tp be mixed with clays for making porous products. Such brick are less costly than those made from kieselguhr.

7. Water smoking. ANON. *Rev. Mat. Constr. Trav. Pub.*, **140,** 73B (1921).—Repetition of general principles—no new information.

8. Rules for the proper drying of large piece and hollow clay ware. ANON. *Rev. Mat. Constr. Trav. Pub.*, **137,** 24B (1921).—A very general discussion with no new information.

9. Prevention of scaling of burned clay pipes. P. S. *Rev. Mat. Constr. Trav. Pub.* **140,** 76B (1921).—Scaling is due to laminations in the clay, poor mixing and grinding of the batch, faulty press machines, and unequal heating in the kilns. Scaling occurs during the dehydration period, 300°–420°, but is in evidence only after salting and during the cooling period.

LOUIS NAVIAS

Apparatus and Instruments

10. Separation of slimes from liquids by centrifuging. BERTHOLD BLOCK. Charlottenburg. *Chem. App.*, **8,** 13–6, 23–4(1921); cf. *C. A.*, **15,** 779; 3 cuts.—This is the 6th supplement to B.'s article (*C. A.* **14**, 1872); in it he discusses power consumption. J. H. MOORE (*C. A.*)

11. Recent developments in grinding. CARL NASKE. *Z. Ver. deut. Ing.*, **64,** 469–75, 619–22, 980–5, 1109–13(1920).—A review of developments in crushing and grinding machines since 1910, with illustrations. Jaw-crushers, rolls, impact pulverizers, ball mills, tube mills; classifiers, sieves, conveyors, air-transportation systems; revolving furnaces, shaft furnaces; typical grinding layouts for aniline, superphosphate, carbide, ammonium salts, lime and Portland-cement plants, are described. W. C. EBAUGH (*C. A.*)

12. Works standardization of pyrometers. R. GATES. *J. Inst. Elec. Eng.* (London), **57,** 317–21(1920). C. G. F. (*C. A.*)

Chemistry, Physics and Geology

13. Silicic acid. VICTOR LENHER. Dept. Chem. Univ. Wis. *J. Am. Chem. Soc.*, **43,** 391–6(1921).—**Effect of fine grinding on silica.**—Experiments show that pure water alone will cause finely ground quartz to go into colloidal solution. Similar experiments with orthoclase gave similar results. **Chemical action of water on silica.**—The action of water on silica is that of a solvent to produce a silica gel. The more finely divided the silica, the more rapid the action. The action is accelerated by heat and with water at high pressures the hydration of large sized quartz crystals and of fused quartz takes place readily. At 400° water will slowly gelatinize all fused silica ware on the market today. **Effect of pressure on silica gels.**—Dehydration of silica gels by pressure was investigated up to a pressure of 2200 kg./cm., the water content decreasing continuously with increasing pressure from an original content of 98% down to only a few per cent. Ed.

14. Record production of borax in 1920. ANON. *Chem. & Met. Eng.*, **24,** 702(1921).—The quantity of borax produced and sold in the U. S. in 1920 was 35,280 short tons, valued at $5,674,000. This is a record production and value, exceeding even those of 1919—28,518 tons and $4,351,891—which were higher

than those of any previous year. For many years borax has been manufactured in the U. S. from the mineral colemanite, a calcium borate, which is mined in Calif., but for the last two years some borax has also been obtained from the water of Searles Lake, Calif. H. F. S.

15. Bauxite in West Africa. *Min. Mag.*, **24,** 189(1921).—From a report by A. E. Kitson, Director of the Geological Survey of the Gold Coast, information is obtained concerning the bauxite deposits of Mount Ejuanema. The bauxite, as exposed in a number of shafts, is within a few feet of the surface and averages $20^1/_4$ ft in thickness of which $12^1/_2$ ft. is massive and the remainder rubbly bauxite mixed with finely granular red bauxite. An estimate gives the total quantity available as three million tons. A peculiarity of the deposits is the quantity of CO_2 gas apparently given off by the bauxite making some of the workings dangerous unless special precautions are taken.

16. New talc grinding capacity of the United States. R. B. Ladoo. *Eng. & Min. Jour.*, **111,** 752(1921).—An abstract of a recent number of the *Reports on Investigations*, U. S. Bureau of Mines.

17. Mining chrome ore in Turkey. R. W. Lane. *Eng. & Min. Jour.*, **111,** 749–750(1921).—At Macri on the coast of Asia Minor opposite the Isle of Rhodes, there are a number of chrome mines only five of which are near enough to the shore to be mined profitably. Of these the three largest are operated on a long term lease by an American corporation which sends about 80% of the 25,000 ton output to America and the remainder to Europe. The ore is of good quality, running 40–45% chromic oxide with 6–8% silica. Due to present primitive methods the production is limited but with contemplated modern installation the output will be increased to 100,000 tons.

18. South American mining fields and practice. W. H. Stover. *Eng. & Min. Jour.*, **111,** 544(1921).—Besides a discussion of oil and metal mining there is a short description of the occurrence of chromite in Bahia. 30,000 tons of ore running 38–47% chromic oxide have been mined and more than twice that much still remains. The genesis of the ore is not explained but it is stated that it is associated with "quartz, hornblendic rocks" and gneisses. Serpentine, which is usually present in chromite deposits, occurs sparingly.

19. The origin of graphite. T. H. Clark. *Econ. Geol.*, **16,** 167–183 (1920). —Most of this paper is given over to a classification and discussion of the various types of deposits. The main object however is to call attention to the possibility of the origin of graphite from the carbon dioxide liberated from limestone by contact metamorphic action.

20. Mica in 1919. H. Imsley. *Min. Res.*, **1919,** Part. II, 269–277(1921).— During 1919 the production of sheet mica decreased 6% in quantity and 34% in value from that of the preceding year. The large decrease in value is probably due to a relatively larger production of the smaller and less valuable sheets since the prices for the individual sizes remained the same as the preceding year or showed a slight increase. The production of scrap mica showed

a considerable increase in both quantity and value. Tables are given showing production by states, prices, imports, and exports for the last six to ten years. The last few pages are devoted to short discussions on the Nature and Occurrence, Distribution, Physical Properties, Forms and Classification, and Uses of mica.

21. Talc and soapstone in 1919. J. S. DILLER. *Min. Res.*, **1919,** Pt. II, 265–268(1921).—During 1919 the production of talc showed a decrease of 13% in both quantity and value. North Carolina, Massachusetts, Pennsylvania, and Georgia showed an increase during this period while California, Virginia, Maryland, New York, and Vermont showed a decrease. Tables showing the distribution and value of imports follow a brief discussion of the occurrence and uses of talc. The soapstone production shows an increase of nearly 8% in quantity but a decrease of 8% in value. D. D. SMYTHE

Refractories and Furnaces

22. Convection of heat and similitude; heat-loss results from model experiments. A. H. DAVIS. *Phil. Mag.*, **40,** 692–703(1920).—The heat-losses from a hot body may be due to conduction, radiation, and convection. While the two former may be calculated, if the constants of the materials and surfaces be known, the loss by convection is complicated by its dependence on the geometrical form of the surface. Although for the simplest forms (spheres, cylinders, etc.) the effect may be calculable, in general it can only be found by experiment, using either the actual object or one of similar form. Evidence available in published data indicates that, for heat-loss from a body, an excellent first approximation can be obtained from experiments with a model. The principle of similitude affords a convenient method of expressing experimental results. ED.

23. Refractory materials; ganister and silica rock; sand for open hearth Steel furnaces; dolomite; petrography and chemistry. H. H. THOMAS, A. F. HALLIM and E. G. RADLEY. *British Geol. Survey,* **16,** 1–115(1920).—Gives analysis of various types of silica rock and dolomites together with discussion of the same. Numerous excellent micro-photographs are shown illustrating both the original structure of the refractories and the structure developed after use in the furnace.

24. Experiments in the use of refractories. *Eng. & Min. Jour.*, **111,** 586 (1921).—An abstract of a recent number of the *Reports of Investigations,* U. S. Bureau of Mines.

25. Meeting emergencies at a chromite plant during the war. S. H. HAMILTON. *Eng. & Min. Jour.*, **111,** 712(1921).—Describes emergency methods used in chromite treatment in N. Carolina due to lack of supplies during the war.

26. Foreign graphite in 1919. A. H. REDFIELD. *Min. Res.*, **1919**, II, 181–210(1921).—Gives data on the production of graphite in all of the important foreign localities. A number of maps illustrate the locations of the fields and a graph is given showing the relative production of the various countries from 1910 to 1919.

27. American clay in graphite crucibles. *Eng. & Min. Jour.*, **111,** 592 (1921).—An abstract of a recent number of the *Reports of Investigations*, U. S. Bureau of Mines.

28. Chromite in 1919. J. S. DILLER. *Min. Res.*, **1919,** I, 87–91(1921).—Due to the decline in prices a little over one-third of the chromite produced in the United States in 1918 was left unsold. As a result there was a decrease of nearly 94% in the production during 1919. Tables are given showing chromite production by various states and counties, also a list of producers most of whom are located in California. The imports of chromite (for which a table is also given) show a drop which is not nearly as large as that of the domestic production.

29. Magnesite in 1919. C. G. YALE and R. W. STONE. *Min. Res.*, **1919,** I, 227–235(1921).—During 1919 the production of domestic magnesite fell off 32%. Some magnesite was imported from Europe and Mexico but the imports from Canada fell off resulting in a decrease of 24% in the imports. In the early part of 1919 the domestic producers were nearly all shut down due to the buyers holding off in expectance of cheap foreign material. This supply did not develop and as a result the buying of domestic magnesite was resumed. A bill designed to protect the domestic industry was introduced in Congress in 1919 but has not been enacted into law as yet. The last few pages of the paper are devoted to short descriptions of the various localities in California, Washington and New Mexico. D. D. SMYTHE

30. Air cracks in refractories. DR. FISCHER. *Tonind. Ztg.*, **44,** 1270 (1920).—F. differentiates between air cracks and shrinkage cracks. Air cracks are caused by rapid heating and cooling while shrinkage cracks develop during firing. Air cracks are very fine while shrinkage cracks are wide. When a piece of the ware is broken it usually cracks along the air cracks. H. G. SCHURECHT

31. Cements for joining refractory bricks. ANON. *Rev. Mat. Constr. Trav. Pub.*, **136,** 11B(1921).—The effects of the addition of various materials on the fusibility of a clay are given. The fusion temps. are given in cones.

	Materials Added					
% of material added	Portland cement	Lime	Asbestos	Salt	Carborundum	First class refractory brick waste
0	30	30	30	30	30	30
3	..	..	28–29	..	..	..
4	27	20–26	..	..	..	..

% of material added	Portland cement	Lime	Asbestos	Salt	Carborundum	First class refractory brick waste
5	..	..	..	26	29	..
6	20	..	19–20	..	..	..
8	19	17–18	..	..	..	..
9	..	..	18–19	..	..	..
10	15	..	..	14	29	..
12	..	11	..	..	..	..
15	..	..	..	5	29	..
16	..	10	..	..	..	..
20	13	..	..	..	29	..
24	..	..	..	..	..	..
25	..	..	..	..	..	30–31
30	11	..	..	..	29	..
40	8	..	..	..	29	..
50	..	..	..	..	29	31

Carborundum and refractory brick maintained the refractoriness,—the rest of the materials lowered it considerably. LOUIS NAVIAS

32. A refractory manufactured from mica. ANON. *Rev. Mat. Constr. Trav. Pub.*, **136,** 15B(1921).—The waste mica from porcelain factories is mixed with clay or with clay and crushed quartz and fired to a temp. sufficiently high to fuse the mica. The resulting product is a good refractory and a good electrical insulator. ED.

33. The recovery of heat from flue gases, and the reheating of air. ANON. *Rev. Mat. Constr. Trav. Pub.*, **136,** 6B(1921).—The heat in flue gases may be utilized in a "recuperator" to preheat air going to the fire-box or to dryers. The "recuperator" may be made of ceramic material or of iron or steel,—the first being used for gases of very high temps. The iron or steel "recuperators" come in either tube form or in plate form, the latter form having the greater advantage of (1) better contact of the gas and air with the separating walls,—for alternate layers of air are heated by alternate layers of the flue gases 25 to 30 mm. apart; (2) less resistance; (3) greater surface area for the space occupied. Compared with an "economizer" the "recuperator" is more gas-tight, thereby preventing the entrance of cold air into the hot gas chambers; and is only one-sixth as heavy for equal surface areas. There are two kinds of plate "recuperators"—the first consisting of semi-circular plate air sections, between which the flue gases travel parallel to the diameters. The different paths travelled by the gases and air, make it difficult to obtain good circulation. The second type known as the "Thermix" is composed essentially of ordinary sheet iron and a frame work of small U irons and coils. The coils allow the fluids to drain off, and also help to tighten the joints of the vertical column of plates. The drainage system can be adapted to any particular case. "1 lb. of 'recuperator' will save 50 times its weight of coal."

34. How to insulate a ceramic furnace. ANON. *Rev. Mat. Constr. Trav. Pub.*, **136,** 10B(1921).—Describes the properties of Sil-o-Cel.

35. Certain types of testing furnaces used in the ceramic industries. C. MIRA. *Rev. Mat. Constr. Trav. Pub.*, **136,** 1–5B; **137,** 17–20B(1921). —A description with figs. of various types of testing furnaces described in American and English literature.

36. The water proofing of kiln crowns. BRICK. *Rev. Mat. Constr. Trav. Pub.*, **136,** 12B(1921).—Over the arch is laid, first, an 8 cm. layer of coal cinders then a 3 cm. layer of ground clay and lastly a layer of asbestos sheeting. Over all is put a layer of special tile. These are hollow rectangular tile, each having at one side a protruding cover that overlaps the next tile in its row. The process of mfg. the tile is patented. LOUIS NAVIAS

37. The firing of ceramic ware with petroleum. J. THOMAS-CADILHAT. *Ceramique*, **23,** 145–149(1920); *Tonind. Ztg.*, **45,** 36(1921).—In the stoneware potteries of Mexico, petroleum has been successfully used since 1919. The ware is fired in cylindrical kilns built for coal-firing and slightly changed for the new system of firing. The advantages of petroleum-firing over coal-firing are as follows: 1—A more uniform heat is obtained; 2—the kilns are not chilled by removing ashes as is the case in coal firing; 3—less labor is required; 4—less upkeep is necessary with grate bars; 5—no ashes, dust or slag are obtained; 6—a better control of temp., fuel consumption and kiln atmosphere is possible and 7—it is easier to start and shut off the fire. With a 90 cbm. kiln one pottery reaches cones 9–10 in 24 hrs. and cone 1 in 22 hrs. H. G. SCHURECHT

38. A new physical aid in ceramics. K. M. BALLEY. *Chem.-Ztg.*, **45,** 75(1921).—Ceramic wares when burned even in muffle or sagger kilns, are often ruined by kiln gases. This may be overcome by maintaining a suitable atm. within the muffle or sagger under a pressure about 5 mm. of H_2O greater than that of the kiln atm. An oxidizing atm. is maintained with air or acid vapors, a neutral atm. with CO_2 or N_2 and a reducing atm. with H_2O or CO. C. H. KERR (*C. A.*)

39. Coal-dust firing in America. HUGO BANSEN. *Stahl u. Eisen*, **40,** 1162–5, 1196–1201, 1228–35(1920).—A symposium based on papers in various technical journals. CARLE R. HAYWARD (*C. A.*)

40. Analyzing records of carbon dioxide and combustible gases. ANON. *Elec. World*, **77,** 654(1921); 1 illus.—The chart shown emphasizes the importance of keeping continuous records of combustible gases present in the flue. C. G. F.(*C. A.*)

41. Percentage of carbon dioxide is not final test of good combustion. O. RODHE. *Elec. World*, **77,** 429(1921).—Dependence on CO_2 records alone is misleading, for while low CO_2 generally indicates excess of air, it may indicate poor mixt. of the air. Insufficient air supply causes the presence of CO in the stack, but other influences include poor furnace design, improper firing methods, the use of the wrong quality of coal for the equipment, poor mixt. of the combustible gases and air, and low furnace temp., whereby the gases are cooled below the ignition point before combustion is complete. W. H. BOYTON (*C. A.*)

42. Kinds of chimney losses and their relative importance. O. RODHE.

Elec. World, **77**, 544(1921).—Heat losses in chimneys are either sensible heat of the flue gases or the heat represented in chem. energy in unconsumed combustible gases. Curves show flue losses with varying amounts of CO_2. At the critical point combustion takes place with the greatest economy in fuel consumption. (*C. A.*)

43. German naval specifications for fire-brick used in boiler settings. *Mitt. der Brennkraftechnischen Gesellschaft*, **2**, 51–56; **8**, 57–59; *Tonind. Ztg.*, **44**, 1097–1098(1920).—Heavy dense brick should be used in contact with the coal bed, medium heavy, for contact with flames only and light brick for the remainder. For a no. 1 brick, deformation should be above cone 34, for a no. 2 brick, cone 31–33 and for a no. 3 brick, cones 26–30. The brick in contact with the fuel bed should contain at least 38% Al_2O_3. For a mortar a mixt. of grog and fire clay is specified which vitrifies at cone 10 and has a deform. point of cone 34. H. G. SCHURECHT

44. Clearing of service pipes with highly compressed air or carbon dioxide. F. GRUBER. *Z. Ver. Gas.-Wasserfach*, **61**, 8–9(1921).—Use of compressed air or CO_2 to clear stoppages in service pipes leads to slugs of non-inflammable or explosive gas in the mains, resulting in dangerous extinctions of gas flames or explosions that damage meters. A case of meter damage in Vienna is discussed. ERNEST W. THIELE (*C. A.*)

45. Silica bricks for coke ovens. J. ENZENAUER. *Stahl u. Eisen; Iron & Coal Trades Rev.*, **102**, 232–3(1921).—The Rheinische Stahlwerke has carried out comparative tests on each of 2 batteries of coke ovens, one made of silica bricks with lime binder of compn. Al_2O_3 1.6–1.9%, SiO_2 94.5–95.0, Fe_2O_3 1–1.5, CaO 1.8–2, MgO 0.1–0.15, alkali 0.6–0.8; the other with ordinary clay-bound fire-brick of compn. Al_2O_3 15–17%, SiO_2 79–81, Fe_2O_3 1.8, CaO 0.3, MgO, 0. 3, alkali 1.6. The former has been in use 4 yrs , the latter 3, and yet the former is in much better condition, silica brick being much more resistant to corrosion from salty and wet coals, to slagging and fusing, and to mechanical abrasion. Also, contrary to expectations, the yield of sulfate was not impaired. The time of coking a charge was reduced from 29 to 24 hr. and 18 hr. was thought feasible. The coke from the silica ovens is of better appearance and considerably harder than that from the fire-brick ovens. In spite of the irregular working, the walls have not developed troublesome leaks and losses of gas are rare. The economic efficiency of the plant is very high. Numerical data were obtained on the differences existing between the working of the silica and fire-brick ovens, resp., comprizing the following detns.: gas made per ton of coal with equal charges 10,675–10,790 cu. ft. per battery per hr. 202,450–170,000 cu. ft.; gas consumption per hr. 126,370–105,600 cu. ft.; heat consumption per ton of coal 692–697 cal.; flue temp. 1069–1027°; stack temp., 372–327°; temp. of blast and regenerator gas 1040–993°; temp. in oven 908–804°; temp. of distn. gas in upcast, 456–434°, in receiver, 295–270°; compn. of crude gas % C_nH_m 2.0–1.9, CH_4 22.1–21. 2, H_2 57.6–58.1, CO 5.1–4.5, CO_2 1.8–2.1, O_2 0.5–0.3, N_2 10.8–11.9, cal. per cu. m., 3809–3770; compn. of flue gas % CO_2, 7.3–7.0, O_2 5.5–5.6, surplus air, 29.6–33.3. J. L. WILEY (*C. A.*)

46. Tentative test for slagging action of refractory materials. ANON. *Proc. Am. Soc. Testing Materials*, **20**, I, 620–3(1920).—A tentative standardized test is recommended by Com. C-8 of the Am. Soc. Test. M. The brick to be tested has a refractory ring cemented to its surface. The whole is held at 1350° during the test. Thirty-five grams of synthetic slag, ground to 40-mesh is put within the ring and allowed 2 hrs. to soak in. The brick is finally cut open and the area of penetration measured. The synthetic slag for general use is made to analyze; SiO_2, 19.0; Al_2O_3, 12.89; Fe_2O_3, 15.73; CaO, 33.50; MgO, 6.93; MnO, 3.52; Na_2O, 8.50. The m. p. of this slag is 1270°.

C. H. KERR (*C. A.*)

Silica bricks for coke ovens (ENZENAUER) **21.**

47. Magnesite in 1919. CHARLES G. YALE AND RALPH W. STONE. U. S Geol. Survey, *Mineral Resources of U. S.*, 1919, Part II, 227–35 (preprint No. 14, published Mar. 7, 1921). E. H. (*C. A.*)

48. Polymultiple flame combustion in metallurgical furnaces. ANON. *Genie civil*, **76**, 336–7; *Mech. Eng.*, **42**, 405–6(1920).—The principle and the method of operation of the Chantraine metallurgical furnace are described. If a jet of gas passes into air as in an ordinary furnace, combustion occurs on the periphery of the jet, and heat radiates mainly into the air, which is permeable to radiant heat. If a jet of air enters an atm. of combustible gas, the heat radiation nearly all remains in the air of the jet, because the adjacent unburned combustible gas is practically impermeable to radiant heat. The tip of such a flame is many times hotter than that of a flame produced by burning a gas jet in air. The combustion is practically perfect even with a very slight excess of air. The Chantraine furnace consists of a double roof, the lower part of which is perforated. The air enters through regenerators, and fills the space in the double roof, passing thence down into the furnace. Gas is conducted from producers to the furnace, which it enters at a point just under the perforated roof. The rate of gas flow is so adjusted that there is a continuous sheet of combustible gas under this entire perforated roof at all times. Air enters through the multitude of perforations and combustion takes place in the form of jets of flame, which attain a max. temp. because the heat of combustion radiates back into the air itself, rather than through the sheet of combustible gas, which is practically impermeable to such radiation. The products of combustion are exhausted solely by the pressure in the combustion chamber, whereas in the furnace of ordinary type much heat is wasted by overheating the sides and roof of the furnace. Such overheating does not take place in the Chantraine system because the sheet of combustible gas protects the roof and sides and, further, because the air entering through the perforations in the roof keeps down its temp. The heat is conveyed very directly and efficiently by the compact bundle of jets or darts of flame to the charge in the furnace. Undesirable oxidation may be prevented and an economy of fuel as great as 40% may be effected. Maintenance costs and metal losses are lower. Steel melting and reheating furnaces may be advantageously constructed on this system.

JAS. O. HANDY (*C. A.*)

49. Heat flow in the checkerwork of blast stoves and regenerative chambers. G. NEUMANN. *Stahl u. Eisen*, **40,** 1473–9(1920).—The thickness of the brick is not so important as previously supposed. Aside from lessening the heating surface bricks 8 cm. thick can be used. Practically nothing is gained by replacing the clay bricks in the lower part of the Cowper stoves with cast iron. The surface works most efficiently in prolonged heating and an equal period of cooling. Tests where the wind period was less than the gas period were less efficient. CARLE R. HAYWARD (*C. A.*)

50. Waste-heat utilization. G. R. MCDERMOTT AND F. H. WILLCOX *J. Western Soc. Eng.* (Chicago), **26,** 60–76(1921).—The gases leaving regeneration or recuperation furnaces commonly waste 35 to 55% of the total heat available in the fuel fired. Non-regenerative furnaces may waste as high as 80%. Much of this heat is not only recoverable but in 1 yr. will yield returns netting 25 to 75% of the cost of installing equipment. This paper refers principally to the waste-heat fire-tube boilers for open-hearth furnaces developed by Bacon for the Ill. Steel Co. at So. Chicago. Specific figures are cited showing amts. of waste gases from certain typical heats and the principles of their utilization are discussed. S. D. KIRKPATRICK (*C. A.*)

PATENTS

51. Lining for rotary kilns or furnaces. A. F. MEYERHOFER. Can. 209,766, Mar. 22, 1921. The lining consists of an inner layer containing a high percentage of fused alumina and an outer heat-insulating layer. (*C. A.*)

52. Refractory material. AUGUST PFAFF. Can. 209,700, Mar. 22, 1921. A refractory material contains a burnt mixt. of about equal parts of zirconia and silicon carbide. (*C. A.*)

53. Combined boiling, crystallizing and calcining furnaces. ALEXANDER ROY. Can. 210,006, Mar. 29, 1921. The app. comprizes a calcining, a drying, a crystg. and a boiling chamber opening successively the one into the other, and means for supplying a heating medium to the calcining chamber. (*C. A.*)

Abrasives

PATENTS

54. Ceramic grinding-wheels. CARBORUNDUM CO. Brit. 155,076, Oct. 15, 1919.—Cracking round the arbor holes of large grinding wheels, composed of abrasive materials or graded abrasive grains bonded together by clays, Na silicate, or org. bonding material, is prevented by making the part round the arbor hole of less d. or with coarser grains than that of the remaining portion of the wheel. The same bonding material may be used for the inner and outer portions or different bonding materials which mature at approx. the same temp. The material near the arbor hole may have no abrasive properties. (*C. A.*)

White Ware and Porcelain

55. The effect of calcination of flints on earthenware bodies. A. HEATH AND A. LEESE. *Pottery Gaz.*, **46,** 616–618(1921).—The sp. gr. of flint may vary from 2.6 to 2.2 according to calcination temp. It is common practice to calcine

one lot of flint in "hardening-on kilns" and another lot in bisque kilns which produces two different products; that which had been calcined at the high temp. would have a sp. gr. of 2.312 while that calcined at the lower temp. would have a sp. gr. of 2.481. This would mean that 32 oz. of slop flint per pt. would contain 21.146 oz. of dry hard calcined flint or 20.102 of easy calcined flint, *i. e.*, a difference of 5%. To compare the effects of the two in an earthenware body, plates were made of bodies containing the same. After firing, it was found that plates containing the hard-fired flint shrank 4% while those containing the easy-fired flint shrank 5%. The porosity of the bodies containing hard-fired flint was 20.09% while that of the bodies containing the easy-fired flint was 17.83%. On submitting the plates to crazing tests it was found that the plates made with easy fired flint crazed first. In a discussion Grimwade stated that when flint is fired to cone 3a it has a bluish cast. Mellor explained that this was due to the sulphur present which forms ultramarine blue with the flint. H. G. SCHURECHT

56. Recent research in manufacture of porcelain insulators. ALFRED SILL. *Elec. Rev.*, **78,** 389–92(1921).—A carefully prepared review.
C. G. F. (*C. A.*)

57. Burning stoneware. CH. S. *Rev. Mat. Constr. Trav. Pub.*, **140,** 67–69B(1921).—Stoneware bodies containing considerable quantities of lime, should not be heated above cone 4a, for the lime tends to form silicates, that are both fluid and corrosive, penetrating the pores and attacking the less fusible materials; while magnesia gives under similar conditions very viscous silicates, whose chemical reactions are retarded by their poor mobility. The opposite results are true of magnesia at temp. above that obtained in the burning of stoneware. Feldspathic stoneware, without lime, may be heated to the fusion point of the feldspar—cone 9 or 10. Clays for stoneware should be plastic, and attain their maximum shrinkage at relatively low temperatures, *i. e.*, between cones 07a and 4a. Their large iron content colors them brown unless sufficient lime is present to whiten them. If sulphates are present in the body, a basic or neutral glaze, fusing between cones 01a and 05a should be used. In the absence of sulphates an acid glaze is preferable. Fuel free from sulphur compounds should be used, otherwise sulphates will be formed, and will attack the acid glaze. Firing should be carefully manipulated, to allow for the burning out of the carbonaceous matter and for the proper oxidizing of the glaze.

58. Furnace atmospheres and some of their effects on lead glazes. F. BIGOT. *Rev. Mat. Constr. Trav. Pub.*, **137,** 20–21B(1921).—On firing a body glazed with a glaze consisting of a mix. of minium (Pb_3O_4) and silica, the glaze was found to be only slightly fritted and non-vitrified altho the body itself was well burned. The clay employed was found to contain large lumps of decayed wood containing sulfur in various stages of oxidation. Rapid heating to the maturing temp. gave the same fritted results, while slow heating and maintaining the temp. at incipient redness, for a while gave properly glazed pieces. The following reactions were found to take place. The minium

at high temp. gives up some oxygen ($Pb_3O_4 = 3PbO + O$) which combines with the sulfur dioxide, ($SO_2 + O = SO_3$), the sulfur trioxide in turn combines with the litharge ($PbO + SO_3 = PbSO_4$) thereby yielding lead sulfate, an inert compound. By this means little or no lead oxide is left to combine with the silica, and to vitrify. Weathering sulphur-containing clays will oxidize the sulfur oxides to the sulfate. Maintaining the temp. of the ware at dull red heat will oxidize the carbonaceous matter at a temp. too low for it to reduce the sulfates present, and will also remove the sulfur oxides by calcination, thereby leaving the lead in the form of oxide for the vitrification at the higher temps.

LOUIS NAVIAS

Brick and Tile

59. Crystal glazes for stove tile. ANON. *Tonind. Ztg.*, **45,** 12(1921).—The compn. of some of the glazes experimented with are given below:

	1	2	3	4	5
Pb_2O_3	91	118	141	182	185
ZnO	40	32	24	..	6.5
$CaCO_3$	10	..	..	7	5
SiO_2	60	48	55	60	75
H_3BO_3	25	..	..	...	...
Kaolin	..	15	..	...	15
Feldspar	..	44	44	55	22
Rutile	..	32	16	24	12.5
Molybdic acid	..	..	..	5.5	4

No. 1 was fritted and Fe_2O_3, NiO and CuO added as coloring oxides. The resultant crystals were small and not well formed. No. 2 gave a matt with considerable crystal formation. No. 3 also gave a matt. Expts. were conducted in which rutile and ZnO were replaced by the acids of W, Mo, and V. Star shaped crystals were obtained. Glazes with W, ZnO and rutile showed many small opaque crystals. V produced matt glazes. Glazes with more than 0.15 Al_2O_3 were matt with some crystals. Al_2O_3 free glazes produced the best crystals. Lime is necessary since the CaO-free glazes showed only weak crystallization. The best coloring oxides are CoO and CuO. UO_2 was satisfactory in some cases. Glazes containing Fe_2O_3, Mn_2O_3, and NiO were limited only to small crystals. Glazes 4 and 5 are used in the unfritted condition and were fired in 20–24 hrs. on a body consisting of 10 stoneware clay, 20 kaolin, 35 quartz, 8 feldspar and 7 chalk.

60. Plaster molds for roofing tile. H. KL. *Tonind. Ztg.*, **45,** 57–58(1921).—1700–2000 gms. of plaster of paris is used per l. of H_2O. The plaster should be slowly added to the H_2O rather than the H_2O to the plaster to prevent the formation of lumps. The plaster is then further mixed by means of a beater similar to an egg-beater to produce a more homogeneous mixt.

H. G. SCHURECHT

61. Standardization of brick in Germany. ANON. *Rev. Mat. Constr. Trav. Pub.*, **136,** 10B(1921).—Building brick consist of burned materials of clay, argillaceous earth, or clay partially replaced by sand, crushed quartz or calcined clay. They are divided into three classes (1) "clinkers" having a resistance to compression of 350 kgs. per sq. cm.,(2) hard burned brick with a resistance of 250 kgs. per sq. cm.,(3) building brick of two varieties (*a*) having a resistance of 150 kgs. per sq. cm. (*b*) having a resistance of 100 kgs. per sq. cm. All the bricks should have dimensions 25 cms. long, 12 cms. wide and 6.5 cms. thick. If it is impossible to manufacture them this size the relation between ength, width, and thickness shall be 4:2:1. The limiting absorption for "clinkers" is 5%, for brick of 2nd. class 8%, the others not determined. All brick should withstand the freezing test. The brick are immersed 25 times in water at —4°C and for periods of 4 hours. LOUIS NAVIAS

Bricks

62. The transformation of periodic kilns into a continuous system in a large brick plant together with a description of the plant. ANON. *Rev. Mat. Constr. Trav. Pub.*, **136,** 8–10B(1921).—Descriptions of the changes made by the Citadel Brick and Paving Block Co. of Quebec, Can. with figs. taken from the *Brick and Clay Record.*

63. Lime-silica (building) brick. (Last installment.) C. BING. *Rev. Mat. Constr. Trav. Pub.*, **136,** 5B(1921) —A study of the details of manufacture of lime-silica brick, lead to the conclusions that (1) a chemical analysis of a sand does not determine its value as an ingredient for brick making. An impure sand may have necessary physical properties not possessed by a pure sand. (2) Lime slaked to the proper degree can always be made or obtained. (3 The simpler the brick machine the better is the product. It is unnecessary to make a stronger brick than that required for the safe carrying of the load. Thus a six-story house, has at its base a load of 4 or 5 kg. per sq. cm. (4) The cost of labor shou'd be at a minimum. (5) The firing of the brick should be carried on by experienced men—thereby reducing the cost of fuel. (6) Careful inspection of outgoing products will save much of the expense of replacing damaged material.

64. Resistance to compression of crude clay bricks and masonry. T. Z. *Rev. Mat. Constr. Trav. Pub.*, **136,** 12B (1921).—Due to the shortage of coal in Germany, clay bricks in the dry state have been used for building purposes. Tests on such brick showed the following resistance to compression. The 1st column is for dry brick, the 2nd for brick after being 4 weeks in a moist atmosphere. The 3rd column represents the absorption.

	Kgs. per sq. cm.		
	(1)	(2)	(3)
Machine made.....	42.3	27.2	1.09
" "	34.9	21.1	1.02
Hand made.....	30.9	21.3	1.12
" "	26 1	20.1	0.76

A test made on some pillars composed of 3 to 8 crude brick had a resistance of 9 to 37.1 kg. per sq. cm. while the resistance of normally burned brick is 150 kgs. for 1st quality and 100 kg. for 2nd quality brick. LOUIS NAVIAS

65. Standardization of specifications for building materials, ceramic product. ANON. *Rev. Mat. Constr. Trav. Pub.*, **136,** 7B (1921).—The French standards comm. has adopted the specifications of the tech. comm. of the Minister of War. Machine-made tile, two sizes, 13 and 22 resp. to the sq. m. Texture homogeneous, free from obvious cracks and laminations; ring, clear; color, uniform; surface sufficiently flat to engage an adjoining tile for $^2/_3$ of the distance; frost resistant; free from particles of uncombined lime; cross-breaking strength 100 kg; the last two tests to be made according to the methods established by the testing lab. of the Conservatoire des Arts et Méteirs. ED.

See also No. 75.

Glass

66. Melting-point of glass. F. WEIDERT AND G. BERNDT. *Z. tech. Physik.*, **1,** 121–3 (1920).—The temp., in an elec. furnace, at which a 25 mm. cube of glass embedded in kieselguhr with a diagonal vertical completely flatten out is called the flowing temp. and the temp. at which the apex just starts to flatten, the deformation temp. The mean of these two temps., which only differ by about 20°C, is called the m.p. The following table gives the flowing temp. for several types of optical glass held at the given temp. for the times given.

Glass type (index and ν value indicated)		Flowing temp. in °C		
		½ hr.	2 hr.	6 hr.
Crown	510/634	850	815	775
Crown	516/640	810	795	780
Flint	549/461	740	725	685
Ba Crown	573/575	910	885	860
Ba Flint	580/538	845	805	785
Ba Crown	590/612	845	830	795
Ba Crown	609/589	870	835	820
Flint	613/369	730	695	680
Ba Crown	614/564	840	815	800
Ba Flint	626/393	780	730	685
Flint	649/338	660	645	630

E. N. BUNTING

67. Celon sands for glass manufacture. ANON. *Bull. Imp. Inst.*, **18,** 174–89(1920).—Eighteen samples of sand from dunes near the Jaffna Peninsula on analysis were found to contain from 96.6 to 99.2% SiO_2. In but 2 samples were the heavy mineral and Fe_2O_3 content low enough (0.02 and 0.12%) to permit the use of the sand for the manuf. of the best quality glass; and in those 2 cases the mechanical condition was such that grinding would be necessary. The sand could be used for the manuf. of a glass of medium quality.

R. L. SIBLEY. (*C. A.*)

PATENTS

68. Glass Working, Glass Manufacture. J. KENT. Brit. Pat. 153,824. Feb. 28, '20; *Ill. Off. Jour.* (Pats.) 1670.P.6057, Jan. 19, 1921. Relates to a method of producing a bore in glass without blowing A sealed length of glass tubing, exhausted, or containing gas, is applied to a mass of glass and autogenously united to and then incorporated with it. The combined mass is afterwards shaped to the desired form. Sketches illustrating the method are included.

69. Glass Working Electric Lamp Bulbs. Glass Manufacture. E. A. KRUGER. Germany, Brit. Pat. 156,573; *Ill. Off. Jour.* (Pats.) 1677.P.278, Mar. 9, 1921.

Welding. Relates to the process of dividing glass articles such as electric lamp bulbs, into two parts, and subsequently re-uniting the parts by fusion. According to the invention the line of division follows the direction which insures that the parts are afterwards brought together. WM. M. CLARK

Enamels

70. Porcelain enameling furnaces. C. G. ARMSTRONG. *Chem. Met. Eng.*, **24,** 486–488 (1921). (Paper presented before Chicago Sec., Amer. Ceramic Soc.) —The art of enameling originated in Egypt about 1300 B. C. Enameling of cast iron for industrial purposes was begun in 1850 and of sheet steel in 1860. The first American plant was built at Woodhaven, N. Y. in 1863. At present both full-muffle and semi-muffle furnaces are used, the latter type being more economical of heat but not suitable for coal firing on account of deposition of ash on ware. Elaborate flue systems in the upper walls and roofs of furnaces are seldom useful in extracting heat from waste flue gases and often are a means of extracting heat from the furnaces and causing the flue gases to leave the furnaces at a higher temperature than if they were taken out by means of shorter flues. The logical procedure is to use a recuperator or to use a thin muffle of high conductivity. Carborundum refractories have comparatively great strength at high temp. and a conductivity about 7 times that of fire clay. The use of thin carborundum muffles permits operation with a temperature difference of only 200°F between flue gases and interior of muffle, as against 800° with fire clay. This gives a fuel saving of about 30% and muffle and flue repairs are greatly reduced. H. F. S.

PATENTS

71. Purifying clay, sand or similar materials. G. A. HULETT. U. S. 1,368,396, Feb. 15. Fe and other volatilizable substances are removed from clay, sand or similar materials by heating the material to 350–600° and treating it with phosgene until the volatilizable substances are eliminated. The method is especially adapted for prepg. ingredients of optical glass or clay pots for glass-making.

72. Quartz-glass articles. J. SCHARL. U. S. 1,368,990, Feb. 15. Quartz is heated to a plastic mass in an elec. resistance furnace about a resistance core,

a space being provided between the quartz to be heated and the resistance core by inserting between them a heat-resisting tube such as C impervious to gases for allowing the escape of the gas formed around the core during the heating. (*C. A.*)

Cement, Lime and Plaster

73. The strengths of high magnesia, hydraulic and common limes. ANON. *Tonind. Ztg.*, **44,** 2–3 (1921).—Mortars were prepared of 1 part lime and 3 parts sand and tested for tens. strength after 28 days.

	In air	In water
High magnesia lime.....	3.4 Kg./cm².	1.2 Kg./cm².
Hydraulic lime.....	3.7 "	2.8 "
Common lime.....	2.5 "	... "

The results show that dolomitic limes as well as hydraulic limes produce stronger mortars than common lime.

74. A mortar material of Anhydrite. H. E. SACHSE. *Tonind. Ztg.*, **44,** 1017–1018 (1920).—Hartner found that Anhydrite ($CaSO_4$) ground extremely fine and mixed with water sets to a hard cement especially if the mixt. is alkaline. The action is facilitated by adding 1–3% of lime or Portland cement. The cement is different from Estrich plaster or plaster of Paris. Plaster of Paris when finely ground has very little residue on 4900 mesh sieve (*i. e.*, 177½ meshes per linear inch). When 100 gms. of water are added to 130–170 gms. of plaster of Paris it commences to set in 1½ to 8 mins. The tens. strength is about 17 kg./ cm². and the compress. strength about 100 kg./ cm². With Estrich plaster about ½ passes 4900 mesh per cm². sieve. When 100 gms. of water are added to 280–350 gms. of plaster it sets in about 30 hrs. and develops a tens. strength of about 17 kg./cm². The compress. strength becomes 200 kg. cm². after 14 days and 230 kg./cm². in 28 days. Anhydrite cement was ground to different degrees of fineness and strength tests were made. Sample A was ground until 10% residue remained on a 4900 mesh sieve. B was ground twice as long as A and C five times as long as A. These samples were mixed with 1% Portland cement and their tens. strengths tested, giving the following values:

	24 hrs.	48 hrs.	3 days	7 days	28 days
A	10.0	13.0	14.0	19.0	30.0
B	18.0	20.5	21.5	25.5	35.5
C	22.0	24.0	25.0	34.0	39.5

H. G. SCHURECHT

Cement

75. The effect of mineral oils on cement. A. GUTTMANN. *Tonind. Ztg.*, **44,** 1116 (1920).—The effect of mineral oils on the strength of concrete was investigated and the following results obtained:

	Air		Petroleum oil		Coal tar oil	
	28 days	6 mos.	28 days	6 mos.	28 days	6 mos.
C	210	192	168	185	160	158
K	287	272	242	252	216	249
B	262	288	193	238	191	189

It was found that those cements into which the oil had penetrated the furthest were weakened the most. He therefore suggests the addition of a material which would make the cement impervious to liquids as a means of making Portland cement resist. to mineral oils.

76. Plaster of paris brick. ANON *Tonind. Ztg.*, **44,** 1259(1920).—Brick are made with ashes, sawdust, etc. using plaster of paris as a binder. 1 part plaster, 3 parts ashes and 1.5 parts water make strong brick. 150–210 are made at once by pouring the mixt. in molds. 3000 brick may be made by 2 men in 8 hrs. These brick have a crushing strength of 30 kg./ cm^2. In order to retard the setting about $^1/_4$ the volume of lime is added. H. G. SCHURECHT

77. Plastic gypsum plaster. WARREN E. EMLEY. *Chem. & Met. Eng.*, **24,** 740–741(1921).—When calcined gypsum is subjected to grinding under such circumstances that the water is not permitted to escape from the system, an entirely new plastic product results. Up to a certain limit the degree of plasticity seems to depend upon the duration and speed of grinding. The increased fineness of the plastic gypsum necessitates the use of more water to bring the paste to a given consistency. Yet, in spite of this excess water, the set material will average about 20 per cent stronger than that made from ordinary calcined gypsum. The process slows down the setting reaction somewhat. Samples of this plastic gypsum have been exposed to the air for four months without apparent deterioration in plasticity. It is essential that the product as it leaves the mill shall contain approximately 6.2% water. A patent, covering both the process and the product, has been applied for, and, if granted, will be given to the public for free use of any one in the United States. H. F. S.

78. Outline of the process of lime manufacture. ANON. *Lime*, Brief No. **250,** Nat. Lime Assoc., Washington, D. C. A four page pamphlet consisting of a detailed flow sheet with brief explanation. ED.

BOOK REVIEWS

79. Modern brickmaking. By ALFRED B. SEARLE. 2nd. Edition, revised and enlarged, April 1920, pp. x + 500 with 310 figs. G. Scott, Greenwood & Son, London.—A general treatise on brick making practices in England; only slightly analytical in discussion of methods, appliances and practices, and suggestive of possible ways of progress in the art. Except for some editing, and a few additional catalog cuts of machinery and a chapter of doubtful value on "The selection of a process and plant for making brick" this edition does not differ materially from the first one. There is nothing in the book that can be said to be an addition to present day knowledge of brick making. R. C. PURDY

ACTIVITIES OF THE SOCIETY

Actions of the Board of Trustees

July 11. It was voted to accept the contract drawn up by President Pence with Ross C. Purdy, engaging the latter as Organizing Secretary for the remainder of the year 1921, and General Secretary for 1922.

The appointment of Mr. E. T. Montgomery as Chairman of the White Wares Division was confirmed.

The appointment of Mr. F. L. Steinhoff as Chairman of the Committee on Co-operation was confirmed.

Necrology

Wm. G. Hipp was born in Bolivar, Ohio, July 20th, 1860. In 1865 he moved to Canton where he lived with his parents completing his Public School education and moved to Pittsburgh in 1886. Here he became associated with the Massillon Stone and Fire Brick Company as Secretary and General Manager. In 1888 he moved to Massillon to take charge of the factory at that place. Mr. Hipp was connected with the Massillon Company from the above date until his death. The product of this concern under his management was largely confined to paving brick until 1902 when the Massillon Stone & Fire Brick Company discontinued the manufacture of paving brick and took up the manufacture of refractories. His work in this field had always been very progressive and a large portion of his time was devoted to research. He was successful in developing a special refractory product which is well known throughout the country. His most recent accomplishment was the development of Alumite products, the manufacture of which is being carried on by the Massillon Refractories Company, a concern organized by Mr. Hipp two years ago for the exclusive manufacture of these products. He was its president. The plant was just completed and in production when Mr. Hipp's death occurred on April 2nd, after one week's illness from pneumonia. He enjoyed a very wide acquaintance with the refractory trade and was highly esteemed by all who knew him. His research work, embodying the betterment of refractory products in general, was always foremost with him. His associates and the industry have lost a valuable worker. He was an active member of the American Ceramic Society from 1900 until his death. Interment was made at Westlawn cemetery, Canton, Ohio.

JOURNAL AMERICAN CERAMIC SOCIETY

Preparation of Abstracts

Every article in THIS JOURNAL is to be preceded by an abstract prepared by the author and submitted by him with the manuscript. The abstract is intended to serve as an aid to the reader by furnishing an index and brief summary or preliminary survey of the contents of the article; it should be suitable for reprinting in an abstract journal so as to make a reabstracting of the article unnecessary. The abstract should, therefore, **summarize all new information completely and precisely.** Furthermore, in order to enable a reader to tell at a glance what the article is about and to enable an efficient index of its subject matter to be readily prepared, the abstract should contain **a set of subtitles** which together form a **complete and precise** index of the information contained in the article. This requires at least one and often several subtitles even for a short abstract.

In the preparation of abstracts, authors should be guided by the following rules, which are illustrated by the abstracts in THIS JOURNAL for February and March, 1921.* The **new information** contained in an article should first be determined by a careful analysis; then the subtitles should be formulated; and finally the text should be written and checked.

Rules

1. **Material not new** need not be analyzed or described in detail; a valuable summary of a previous work, however, should be noted with a statement indicating its nature and scope.

2. **The subtitles should together include all the new information;** that is every measurement, observation, method, improvement, suggestion and theory which is presented by the author as new and of value in itself.

3. **Each subtitle should describe the corresponding information so precisely** that the chance of any investigator being misled into thinking the article contains the particular information he desires when it does not, or vice-versa, may be small Such a title as "A note on blue glass," for example, is evidently too indefinite a description of information regarding "Absorption spectra of glass containing various amounts of copper-cobalt and chromium-cobalt." General subtitles, such as "Purpose" and "Results" should not be employed as they do not help to describe the specific information given in the article.

4. **The text should summarize the authors' conclusions and should transcribe numerical results of general interest,** including those that might be looked for in a table of physical and chemical constants, with an indication of the accuracy of each. It should give all the information that anyone, not a specialist in the particular field involved, might care to have in his note book.

5. **The text should be divided into as many paragraphs as** there are distinct subjects concerning which information is given, but no more than necessary. All parts of subtitles may be scattered through the text but the subject of each paragraph, however short, must be indicated at the beginning.

6. **Complete sentences** should be used except in the case of subtitles. The abstract should be made as readable as the necessary brevity will permit.

7. The ms. of all abstracts must be typewritten and double or triple spaced.

* The rules were prepared by the Research Information Service of the National Research Council. The Society is indebted to Dr. G. S. Fulcher of the Corning Glass Works (formerly with the National Research Council) for the rules and the illustrative abstracts.

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12-21
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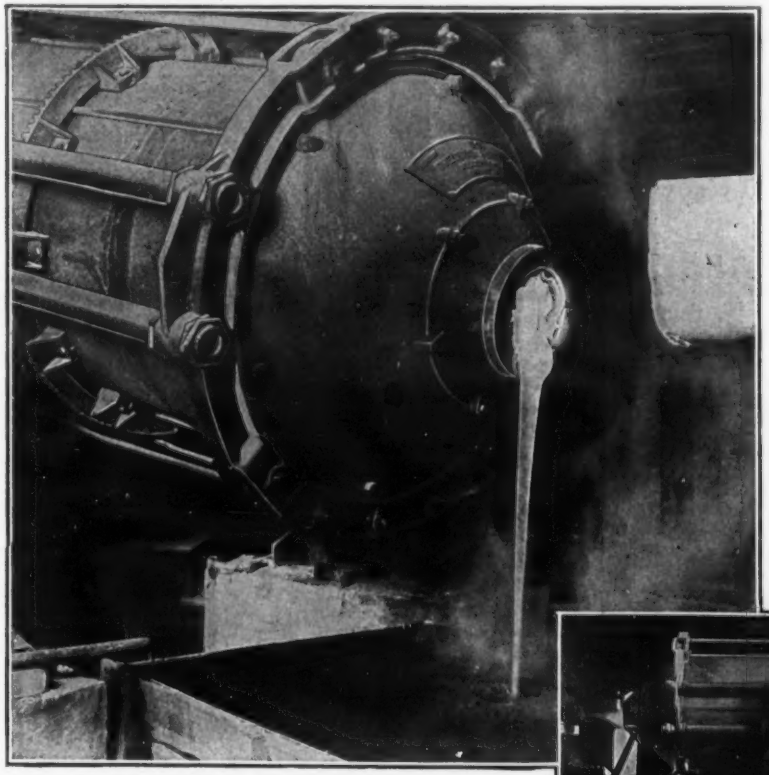

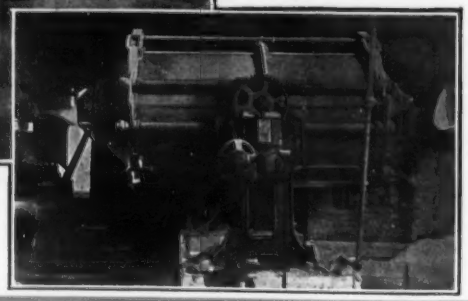

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12-21

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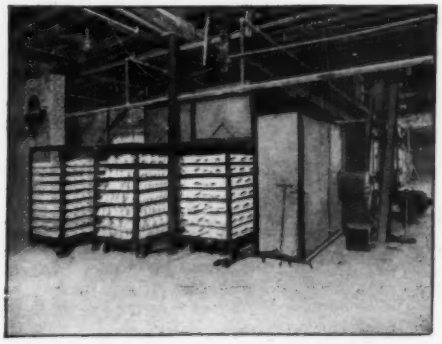

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Clay (Fire)
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Clay (Pot, Tank Blocks)
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Clay (Potters)
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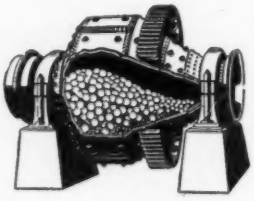
It Classifies As It Grinds



are ground in Hardinge Mills along with a host of other substances.

Our booklet explains why the mill has been adapted to so many uses. Write for a copy.

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The Justice Radiated Heat and Waste Heat Dryers for drying structural clayware have no equal in economy and efficiency.

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REALLY washed—Highest percentage clay substance

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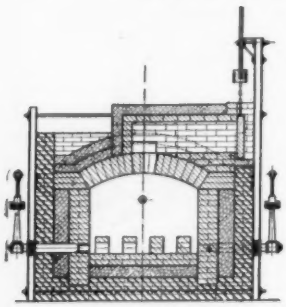

Direct fired gas	**1.0c**
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8th Coast Artillery Armory

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It proves that SIL-O-CEL, because of its high non-conductivity, has reduced heat radiation from the Kiln to a minimum. Can you estimate what this means in fuel saved? Do you know of the numerous other advantages that are resultant from this necessary control of heat produced by SIL-O-CEL?

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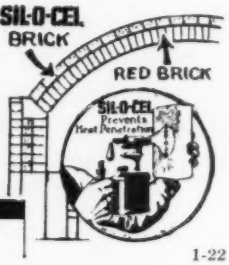

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PEMCO puts your Plant in operation, shows you how to do the work right and keeps a general supervision over your Enameling Department to insure maximum production.

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The Porcelain Enamel & Manufacturing Co.

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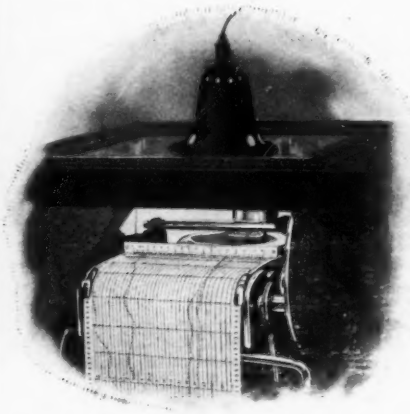

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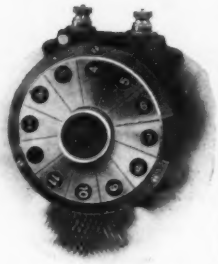

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USE
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All Sizes and Lengths for either Platinum or Base Metal Couples
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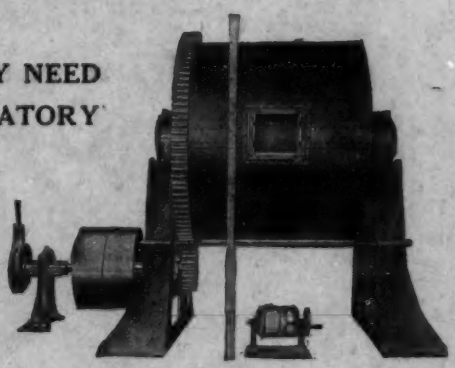

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